```
=> d his

     (FILE 'HOME' ENTERED AT 09:22:38 ON 12 APR 2000)

     FILE 'USPATFULL' ENTERED AT 09:22:40 ON 12 APR 2000
L1             15 S LEC AND ELAN
L2             14 S L1 AND ADDRESS###
L3             10 S L2 AND NAME AND SERVER
L4             10 S L2 AND NAME AND SERVER##
L5              0 S L2 AND NAME SERVER##
L6              0 S L2 AND (DOMAIN# (5A) SERVER##)
L7            322 S NAME SERVER#
L8             29 S L7 AND ATM
L9              7 S L8 AND MAC
L10            35 S ARP CACHE##
L11            35 S L10 AND ADDRESS?
```

=> d 32 pn hit

L11 ANSWER 32 OF 35 USPATFULL

PI US 5509123 19960416

DETD Returning to FIG. 3B, the forwarding information base 233' is connected to each of a plurality of "protocol" forwarding engines 234' which are further illustrated in FIG. 3E. The protocol forwarding engine object 234' includes a forward and service object 239' connected to each of an access list object 240', a next-hop cache object 241', and a framing object 242'. The framing object 242' is connected to each of **address** cache object 243' and network interface object 237'. The next-hop cache object 241' is connected to the network forwarding table object 233', or FIB in FIG. 3B. Returning to FIG. 3B, each network interface object 237' is connected below to a network media device driver 238'.

DETD In this prior model, each protocol always gets the packet and then decides if it was appropriate for the interface. It is a centralized model with the protocol layer being the funnel for all packets entering and exiting the system regardless of the interface the packet came in on. Also, because it is centralized, each layer must have knowledge about every specific interface. For example, all configured interface information such as MTU size, forwarding enabled/disabled state, configured network **addresses** and masks, data-link framing options, filter access lists, etc, must be accessed by each layer as it processes/forwards the packet. This model puts overhead into each layer and is very limiting in supporting new interfaces, media, and protocols, as each layer must be modified. An example of overhead is that if a packet is received for a protocol that is not enabled, it is not dropped until it has been passed up to the correct protocol layer.

DETD In order to provide a consistent-forwarding model for packets destined for "local" delivery into the "host" CPU, the host is treated as an internal interface with a destination **address**. The delivery of host destination packets remains in band to the forwarding function.

DETD The operation of the forwarding engine can now be described with regard to FIG. 4. In response to receipt of a data packet on interface object-1 (11), the interface object 11 calls a service method in its bound forwarding engine object 12. The service method removes the sublayer framing on the network packet and performs a validation and extraction of the destination network **address** from the network packet. The service method then provides a next-hop determination by looking up the destination network **address** in a cache memory of active **addresses** to determine a destination forwarding engine object handle, and, if the destination network **address** is not located in cache memory, accessing a forward look-up table 20 for the best route to the destination network **address**, and then updating its cache. The method then returns the destination forwarding engine object handle.

DETD Assuming the destination is interface N, upon receipt of the destination forwarding engine object handle, a service method is called in the destination forwarding engine object 15. The service method validates the destination **address**, performs a look-up in an **address** cache to obtain a media specific **address** of the destination, and the service method then reframes the packet and

transfers it to the destination interface 14.

DETD The forwarding engines of this invention are implemented using object-orientated methodology and are written in the language C++. By having C++ objects, each forwarding engine has its own data portion 13, 16, 19 that is specific to itself, e.g., interface and media information, **address** resolution tables, configuration information, etc. However, the method portion 12, 15, 18 of each engine is common and is shared by all similar engines.

DETD converting network layer **address** to physical **address**

DETD The same concept holds true on the forwarding side. Each protocol FAS registers itself with the forwarding table for that protocol. This is done by registering its network **address** and masks along with a pointer to its base class with the internal forwarding table. This table is used by the service method of each protocol FAS to determine which FAS should be invoked to forward the packet, i.e.,

DETD FAS.sub.-- ptr=Forwarding Table.sub.-- Lookup (Destination.sub.--Network.sub.-- **Address**);

DETD Routers must make a forwarding decision for every packet received as to what interface and next hop gateway to forward to. The decision is laborious because a number of competing route choices exist in the Forwarding Information Base (FIB), and the best route must be selected based on **address** match, metrics, quality of service, route type or class, network versus subnet granularity, etc. Once the route decision is made, it is common in router applications to cache that choice to speed up the decision for later packets having the same destination. How this caching is implemented varies wildly but is typically kept of small fixed size and is feature poor.

DETD This invention comprises an object-oriented and feature-rich caching to provide a short-cut handling for later packets received with the same source and destination **addresses**. A separate cache exists for each network interface by containing cache objects in each forwarding engine (see for example next-hop cache object 241' and **address** cache object 243' in FIG. 3E).

DETD This invention provides a base class ACache which is protocol independent. **Addresses** are kept as unsigned long integers. ACache does not support management set static entries; it is strictly dynamic. ACache supports:

DETD Setting an entry is done by hashing the source and destination **addresses** into a one byte hash code and linking the entry into a "bucket" quickly accessible by that code. The entry itself has a generic base class as seen by ACache, but what is actually stored is a derived entry which may contain protocol-specific data. This allows each cache to function exactly the same regardless of specific protocol-derived classes.

DETD As part of forwarding packets, the IP forwarding engine methods (1) validate packet **addresses**, (2) filter against an access list, and (3) retrieve the next hop from the FIB. These procedures are inherently slow, so the results of these procedures once obtained, such as **address** validity, are cached and corresponding procedures are provided in IPACache to lookup the same results quickly.

DETD Martian (invalid) **addresses**

DETD Each of these procedures is passed the source and destination **addresses** from a packet, hashes them and looks up entries linked in the "bucket" for that hash code. It checks each linked entry to see if it matches exactly both the source and the destination. If it finds a match it returns the entry data for that function. For the Martian lookup the **address** validity, yes or no, is returned. For access control lookup (see access list object 240' in FIG. 3E) an additional protocol and port parameter must be matched and permission, permit or deny, is returned. For next hop a quality of service parameter must be matched and the next hop is returned.

DETD In general, routing applications allow network management to filter packets based on destination **address**, or on the combination of destination and source **addresses**. It is desirable that each interface of the router be able to maintain a separate set of filter instances--an access list. Most vendors use a linear mechanism and since the list must be checked for each packet being forwarded, throughput slows down linearly as the list gets larger.

DETD B.3.3 Wild Card **Addressing**

DETD Although **addressing** is the protocol-specific part of the access list entry, all protocol FAC derived classes support some special case **address** values which stand for a range of **addresses**. For example, in IP an **address** is paired with a mask and 0's in the mask are wild cards matching anything in the corresponding part of the **address**. Thus an **address** paired with a mask of all 0's matches everything. This is powerful--to filter out all packets from any source destined to a server, set the access list entry with the server's destination **address** and mask of all 1's, but use a source **address** and mask of 0's.

DETD This provides ease of use in specifying what to filter. For example, to allow all packets through from one subnet and deny all packets from other subnets on the same network requires only two entries. Set the first entry to permit the good subnet and the second entry to deny all subnets of that network by using a wild card for the subnet and host portion of the **address**.

DETD This also allows for discrimination based on interface, not just on **address**--e.g., all source A to destination B permitted on interface 1 but not on interface 2. This is not possible if filtering is only checked on the forwarding side (unless interface is made part of an entry, which is more awkward to administrate).

DETD Standard data link framing formats and protocol identifiers, as defined by the standards committees, such as IEEE, IETF, are realized through specific Framing Objects. Data link framing and media details are embedded in the Framing Objects to relieve the network layer from this knowledge. Where required, methods are provided by the Framing Objects to obtain data link framing and media information in a generic manner, for example, to return the length and value of a data link physical **address**, obtain the length of a data link header, or obtain the media MTU.

DETD Framing Object instances returned from the Framing Object Resource class can be used by the network layer protocol to simultaneously support all valid framing formats for a specific media. Dynamic teaming of network stations and associated framing formats can be achieved. For example, the IP network layer protocol may be communicating with two IP stations on a directly connected ethernet segment using Ethernet Version 2 framing for one IP station and 802.2 LLC with SNAP framing for the other. The Framing Object is retained in the **ARP cache** along with the MAC layer physical **address** to allow the IP network layer to map a framing format, as well as, a physical **address** to an IP station.

DETD

| Name | Derived From |
|---|---|
| Integer Managed Object | Core INTEGER, Managed Object Base Class |
| String Managed Object | Core OCTET STRING, Managed Object Base Class |
| OID Managed Object | |

| | |
|---|---|
| | Core OBJECT IDENTIFIER, Managed Object Base Class |
| Null Managed Object | Core NULL, Managed Object Base Class |
| IP **Address** Managed Object | Core IP **Address**, Managed Object Base Class |
| Counter Managed Object | Core Counter, Managed Object Base Class |
| Gauge Managed Object | Core Gauge, Managed Object Base Class |
| Time Ticks Managed Object | Core Time Ticks, Managed Object Base Class |
| Static Table Managed Object | Core Static Table, Managed Object Base Class |
| Dynamic Table Managed Object | Core Dynamic Table, Managed Object Base Class |

DETD End Systems Group--contains the managed objects which control the **Address** Resolution Protocol (ARP) which maps host **addresses** to physical **addresses** for each router port.

DETD The common forwarding group MIB follows the common component view with the exception of an **Address** Table (see Table 2). If necessary, each protocol specifically defines an **address** table. For example, DECnet does not require configuring an **address** per port and so the **address** table group is not present.

DETD TABLE 2

| The Forwarding Component Group |
|---|
| System (1) |
| Aggregate Counters (1) |
| Interfaces (2) |
| Config (1) |
|     Config Interface Table (1) |
|     **Address** Table (2) |
| Counters (2) |
|     Counters Interface Table (1) |

DETD Config Type **addressing** component resource, consists of the protocol's network **address** table or system wide network **address**.

DETD FIB Type--This resource is a forwarding information base. Most network protocols have them and are used by the forwarding engines to lookup the next hop interface of of a given network **address**. Routing protocols use the FIB to deposit their best next hop interface of a given network **address**. These **addresses** are learned dynamically through protocols. There is no common MIB template for this type.

DETD ARP Type--This is an ARP resource (ARP=**Addressing** Resolution Protocol). This resource is of class Interface and Component resource.

ARP is used to resolve the physical interface **address** of a given network **address**. This type has a co[illegible] MIB template defined.

DETD Component Resources is a base class that defines the functional implementation of a component object. For example, Base Config defines the functional implementation for configuring and accessing the network **address** per interface.

CLM What is claimed is:

17. The apparatus of claim 7, further including means for mapping a network layer **address** to a framing format, and means for mapping a physical layer **address** to a network layer **address**.

```
=> d his

     (FILE 'HOME' ENTERED AT 13:59:51 ON 12 APR 2000)

     FILE 'USPATFULL' ENTERED AT 13:59:51 ON 12 APR 2000
L1            435 S ADDRESS RESOLUTION#
L2            267 S L1 AND SERVER#
L3            108 S L2 AND ATM
L4             85 S L3 AND MAC
```

L4 ANSWER 61 OF 85 USPATFULL

PI US 5748626 19980505

TI **ATM** communication system with high speed connection-less service function

AB **ATM** communication system capable of realizing a high speed and efficient datagram delivery for the connection-less communication among the terminals in the **ATM** network. In the system formed by a plurality of **ATM** networks inter-networking with each other, each network containing a plurality of terminals, the **ATM** networks with connection-less service function units for managing a connection-less datagram transmission are provided in the **ATM** networks, and the connection-less datagram transmission from each terminal to a destination terminal is performed by resolving a connection identifier for identifying an **ATM** connection connected to a destination side connection-less service function unit associated with a destination side **ATM** network containing the destination terminal, and transmitting datagram from said each terminal to the destination side connection-less service function unit through the **ATM** connection identified by the resolved connection identifier.

SUMM The present invention relates to an **ATM** (Asynchronous Transfer Mode) communication system with a CLSF (Connection-Less Service Function).

SUMM In order to provide the highly efficient and flexible communication services with respect to the increasing demands for the variety of communications such as the image communication and the high speed data communication, there is an eager expectation for the realization of the B-ISDN (Broadband-Integrated Service Digital Network), and the **ATM** exchange scheme is considered as a prospective scheme for actually realizing the B-ISDN.

SUMM The **ATM** exchange scheme is a scheme for realizing the communication service by loading data into a fixed length packet called cell regardless of the attributes of the data, and using this cell as a unit of exchange. The ITU (formerly CCITT) has formally determined this **ATM** exchange scheme as the next generation exchange scheme, and decided to use this **ATM** exchange scheme for realizing the B-ISDN. For this reason, it is highly likely that the demands for the next generation multi-media communication and broadband communication are going to be handled by constructing the public network or the local network based on the **ATM** exchange scheme.

SUMM In recent years, there Is a movement for applying this **ATM** exchange scheme to the LAN (Local Area Network) such as the Ethernet. In this case, the LAN operated under the **ATM** exchange scheme will be referred as the **ATM**-LAN. Such an **ATM**-LAN is expected to have the advantages that the throughput of the LAN can be improved considerably, that it is suitable for the multi-media, and that it is adaptive to the public network.

SUMM Now, one of the features of the **ATM** communication scheme is that its high speed operation realized by the hardware switching of the **ATM** cells. That is, the **ATM** network Is the connection-oriented (CO) network in which the virtual connection (VC) or the virtual path (VP) is set up end-to-end, and the packet called cell

is delivered end-to-end by label multiplexing or label exchanging the VCs or VPs in terms of their identifiers (VCI or VPI).

SUMM The data to be delivered end-to-end is loaded in the payload section of the **ATM** cell, and the **ATM** cell is exchanged and transmitted up to the destination terminal by the hardware switching operation alone without the intervention of the software operation, where the hardware switching operation is carried out by the **ATM** switch according to the VPI/VCI (or the value of the other field such as PT in the **ATM** cell header) contained in the **ATM** cell header.

SUMM In contrast to this **ATM** communication scheme which is the connection-oriented communication scheme, the communication scheme used in the conventional data communication is the connection-less (CL) communication scheme in which the end-to-end connections are not necessarily set up, and the packet is transmitted to the destination terminal as the packet is sent out to the network by attaching the destination data as its part while some node in the network analyzes the destination data and carries out the routing processing. Namely, in the connection-less communication scheme, the data transmission is realized without the procedure for setting up the connections at the terminals. In such a case, the packet to be transmitted to the destination terminal in connection-less manner is called datagram and this data transmission is called the datagram transmission. Thus, in the connection-less communication scheme, the communication is realized in a form of the datagram transmission without the procedure for setting up the connections.

SUMM In such existing terminals or terminals provided with the existing protocols, i.e., the terminal which generates the datagram and outputs it to the destination terminal/network through the **ATM** network, the datagram transmission scheme is used for the terminal to terminal communication. To this end, it is necessary for the terminal and the network to be modified to realize the function for adapting the terminal to the interface with respect to the **ATM**-LAN by replacing the usual LAN board with the **ATM** board such as the Ethernet board or by using the terminal adaptor (TA), the function for loading the datagram into the **ATM** cell somehow at the terminal, and the function to deliver the datagram to the destination terminal indicated by the destination address at the network. Here, the terminal include the gate-way between the existing LAN and the **ATM** network.

SUMM To realize these functions, the datagram delivery scheme using the CLSF has been used conventionally. In this datagram delivery scheme, the CLSF processing unit is provided within the **ATM** network, and all the datagrams are collected there once. In other words, the CLSF processing unit is connected with all the datagram terminals by PVC (Semi-Permanent VC)(or VC, VP, PVC, or PVP), and the terminal wishing to transmit the datagrams assembles the **ATM** cells for all the datagrams to be transmitted, and transmits the **ATM** cells to the VC directed toward the CLSF processing unit. The CLSF processing unit then reproduces the received datagrams, and selects the VC connected to the destination address by analyzing the destination address of the datagrams, and then re-assembles the **ATM** cells for the datagrams and transmits the **ATM** cells to the selected VC. In a case the VC connected to the destination address cannot be found while there are other CLSF processing units within the network, the CLSF processing unit transmits the re-assembled **ATM** cells

to the next stage CLSF processing unit which is expected to contain the terminal with the destination address or which is determined by the routing rule in advance.

SUMM Here, it is not absolutely necessary for the CLSF processing unit to analyze the destination address after reproducing the datagrams, and transmits the **ATM** cells after re-assembling the **ATM** cells. For instance, in a case the destination address is contained in the to cell among the **ATM** cells for the datagrams, the destination address of the first cell alone can be analyzed and then transmitted to the destination terminal, and then the subsequent cells of the **ATM** cells for the datagrams can be sequentially transmitted to that destination terminal.

SUMM Another scheme for transmitting the datagrams to the destination terminal is to set up the **ATM** connection, such as VC to the destination address, and the **ATM** cells for the datagrams are delivered through this VC. However, in this scheme, there is a serious problem concerning the selection of the destination terminal with respect to which the VC is to be set up. Namely, there are enormously many terminals to which the datagrams can possibly be transmitted in practice, and in addition the generation of the datagrams is more bursty compared with the speech data, etc., so that to set up the enormously many connections is going to be a considerable waste of the network resource.

SUMM Furthermore, in a case of realizing the connection-less communication in the conventional **ATM** network, the **ATM** connection is always terminated at the CLSF processing unit, and the protocol processing for the upper layers above the AAL layer such as the protocol for the connection-less service called CLNAP (Connection-Less Network Access Protocol) is carried out. In other words, even in a case of the datagram transmission between the quite nearby terminals, the **ATM** connection is going to be terminated once at the CLSF processing unit. Also, in a case of the datagram transmission between far distanced terminals, it becomes necessary to pass through a plurality of CLSF processing units at each one of which the protocol processing above the AAL layer must be carried out.

SUMM In general, the protocol processing above the AAL layer such as the CLNAP is realized by the software processing so that the processing speed is slow compared with the processing below the AAL layer which is usually carried out by the hardware processing. Also, it is necessary for the CLSF processing unit to carry out the analysis of the address data such as the network layer address data in the datagrams for not just the transmissions to the terminals of the network supported by that CLSF processing unit itself but also for the transmissions to the terminals of the network supported by the other CLSF processing unit as well, so that the datagram transmission processing load is going to be concentrated on the CLSF processing unit. For these reasons, it has been difficult to realize the high speed communication in the connection-less communication (datagram delivery) among the terminals of the conventional **ATM** communication system.

SUMM There is also an element called "bridge" which has the similar function as the router in realizing the inter-LAN connection. In this bridge, in contrast to the router which determines the destination LAN by analyzing the destination network layer address, the destination LAN is determined

by analyzing the data link layer address (**MAC** address). Namely, the bridge realizes the inter-LAN connection by analyzing the destination **MAC** address of the datagram and passing the datagram through to another LAN when the obtained **MAC** address is not destines within its own LAN.

SUMM However, in a case of the **ATM**-LAN, these router, bridge, and brouter are going to terminate the connection at the layer 3 or the layer 2 forcefully and the processing for the layer 3 and layer 2 after the termination is most likely handled by the software processing. For this reason, for the transmission over the LANs, the speed and the capacity of the communication can be considerably lowered compared with the communication within the LAN. Also, in a case of providing the router, bridge, brouter, etc., the VP/VC cannot be set up over the LANs because the layer processing above the **ATM** layer between the end points is carried out at the routers.

SUMM Thus, in the conventional **ATM**-LAN, the layer 3 (network layer) processing must be carried out at the physical boundary of the networks, because the physical network boundary is the boundary of the OSI layer 2 (data link layer), and therefore the router must be provided at the physical network boundary for this reason.

SUMM It is therefore an object of the present invention to provide an **ATM** communication system capable of realizing a high speed and efficient datagram delivery for the connection-less communication among the terminals in the **ATM** network.

SUMM It is another object of the present invention to provide an **ATM** communication system capable of setting the topology of the network layer independently from the topology of the physical network.

SUMM According to one aspect of the present invention there is provided an **ATM** communication system, comprising: a plurality of **ATM** networks inter-networking with each other, each network containing a plurality of terminals; and connection-less service function means for managing a connection-less datagram transmission in the **ATM** networks; wherein the connection-less datagram transmission from each terminal to a destination terminal is performed by resolving a connection identifier for identifying an **ATM** connection connected to a destination side connection-less service function means associated with a destination side **ATM** network containing the destination terminal, and transmitting datagram from said each terminal to the destination side connection-less service function means through the **ATM** connection identified by the resolved connection identifier.

SUMM According to another aspect of the present invention there is provided an **ATM** communication system, comprising: a plurality of **ATM** networks inter-networking with each other, each network containing a plurality of terminals and the **ATM** networks including a first **ATM** network having connection-less service function means for managing a connection-less datagram transmission in the **ATM** networks, and a second **ATM** network having no connection-less service function means; inter-networking means for inter-networking the first and second **ATM** networks; and connection set up means for setting up a first **ATM** connection between the connection-less service function means of the first **ATM** network and the inter-networking means, and a second **ATM** connection between the inter-networking means and a terminal belonging to the second **ATM** network; wherein the inter-networking means directly connects the first and second **ATM** connections set up by the connection set up means at an

ATM layer, and the connection-less service function means of the first ATM network is assigned with an address data indicating that said connection-less service function means logically belongs to the second ATM network at a network layer, such that the connection-less datagram transmission from said terminal belonging to the second ATM network is performed by using said address data through the first and second ATM connections connected at the ATM layer.

SUMM According to another aspect of the present invention there is provided an ATM communication system, comprising: a plurality of ATM networks inter-networking with each other, each network containing a plurality of terminals and the ATM networks including a first ATM network having connection-less service function means for managing a connection-less datagram transmission in the ATM networks, and second and third ATM networks having no connection-less service function means; first inter-networking means for inter-networking the first and second ATM networks; second inter-networking means for inter-networking the second and third ATM networks; and connection set up means for setting up a first ATM connection between the connection-less service function means of the first ATM network and the inter-networking means, a second ATM connection between the inter-networking means and the second inter-networking means, and a third ATM connection between the second inter-networking means and a terminal belonging to the third ATM network; wherein the inter-networking means directly connects the first, second, and third ATM connections set up by the connection set up means at an ATM layer, and the connection-less service function means of the first ATM network is assigned with an address data indicating that said connection-less service function means logically belongs to the third ATM network at a network layer, such that the connection-less datagram transmission from said terminal belonging to the third ATM network is performed by using said address data through the first, second, and third ATM connections connected at the ATM layer.

SUMM According to another aspect of the present invention there Is provided a method for ATM communication in an ATM communication system formed by a plurality of ATM networks inter-networking with each other, each network containing a plurality of terminals, the method comprising the steps of: providing the AIM networks with connection-less service function means for managing a connection-less datagram transmission in the ATM networks; and performing the connection-less datagram transmission from each terminal to a destination terminal by resolving a connection identifier for identifying an ATM connection connected to a destination side connection-less service function means associated with a destination side ATM network containing the destination terminal, and transmitting datagram from said each terminal to the destination side connection-less service function means through the ATM connection identified by the resolved connection identifier.

SUMM According to another aspect of the present invention there is provided a method of ATM communication in an ATM communication system formed by a plurality of ATM networks inter-networking with each other, each network containing a plurality of terminals and the ATM networks including a first ATM network having connection-less service function means for managing a connection-less datagram transmission in the ATM networks, and a second ATM network having no connection-less service function means, the method comprising the steps of: inter-networking the

first and second **ATM** networks by first inter-networking means; setting up a first **ATM** connection between the connection-less service function means of the first **ATM** network and the inter-networking means, and a second **ATM** connection between the inter-networking means and a terminal belonging to the second **ATM** network: directly connecting the first and second **ATM** connections at an **ATM** layer by the inter-networking means; assigning the connection-less service function means of the first **ATM** network with an address data indicating that said connection-less service function means logically belongs to the second **ATM** network at a network layer, such that the connection-less datagram transmission from said terminal belonging to the second **ATM** network is performed by using said address data through the first and second **ATM** connections connected at the **ATM** layer.

SUMM According to another aspect of the present invention there is provided a method of **ATM** communication in an **ATM** communication system formed by a plurality of **ATM** networks inter-networking with each other, each network containing a plurality of terminals and the **ATM** networks including a first **ATM** network having connection-less service function means for managing a connection-less datagram transmission in the **ATM** networks, and second and third **ATM** networks having no connection-less service function means, the method comprising the steps of: inter-networking the first and second **ATM** networks by first inter-networking means, and the second and third **ATM** networks by second inter-networking means; setting up a first **ATM** connection between the connection-less service function means of the first **ATM** network and the inter-networking means, a second **ATM** connection between the inter-networking means and the second inter-networking means, and a third **ATM** connection between the second inter-networking means and a terminal belonging to the third **ATM** network; directly connecting the first, second, and third **ATM** connections at an **ATM** layer by the first and second inter-networking means; and assigning the connection-less service function means of the first **ATM** network with an address data indicating that said connection-less service function means logically belongs to the third **ATM** network at a network layer, such that the connection-less datagram transmission from said terminal belonging to the third **ATM** network is performed by using said address data through the first, second, and third **ATM** connections connected at the **ATM** layer.

DRWD FIG. 1 is a schematic diagram of a first type **ATM** network block in the **ATM** communication system according to the present invention.

DRWD FIG. 2 is a schematic block diagram of an inter-networking unit in the first type **ATM** network block of FIG. 1.

DRWD FIG. 3 is a schematic diagram of a second type **ATM** network block in the **ATM** communication system according to the present invention.

DRWD FIG. 4 is a schematic block diagram of an inter-networking unit in the second type **ATM** network block of FIG. 3.

DRWD FIG. 5 is a partial network diagram of the **ATM** communication system according to the present invention, showing a first case of the datagram delivery within sub-network.

DRWD FIG. 8 is a partial network diagram of the **ATM** communication system according to the present invention, showing an laternative procedure for the first case of the datagram delivery within sub-network.

DRWD FIG. 10 is a partial network diagram of the **ATM** communication system according to the present invention, showing a second case of the

datagram delivery within sub-network.

DRWD FIG. 11 is a schematic overall network diagram of the **ATM** communication system according to the present invention in a case of the hierarchical network topology.

DRWD FIG. 12 is a schematic network diagram of the network of FIG. 11 for an **address resolution** in a first case of the datagram delivery to external network.

DRWD FIG. 14 is a schematic diagram of an address space view from one **address resolution server** in the case of the datagram delivery to external network shown in FIG. 12.

DRWD FIG. 15 is a schematic diagram of an address space view from another **address resolution server** in the case of the datagram delivery to external network shown in FIG. 12.

DRWD FIG. 16 is a schematic network diagram of the network of FIG. 11 for an alternative procedure for an **address resolution** in a first case of the datagram delivery to external network.

DRWD FIG. 17 is a schematic diagram of an address space view from one **address resolution server** in the case of the datagram delivery to external network shown in FIG. 16.

DRWD FIG. 18 is a schematic diagram of an address space view from another **address resolution server** in the case of the datagram delivery to external network shown in FIG. 16.

DRWD FIG. 26 is a diagram of **ATM** connections in a second case of the datagram delivery to external network.

DRWD FIG. 27 is a schematic overall network diagram of the **ATM** communication system according to the present invention in a third case of the datagram delivery to external network.

DRWD FIG. 33 is a diagram of **ATM** connections in the third case of the datagram delivery to external network.

DRWD FIG. 34 is a schematic overall network diagram of the **ATM** communication system according to the present invention in a case of the flat network topology.

DRWD FIG. 39 is a diagram of **ATM** connections in the first case of the datagram delivery to external network shown in FIG. 37.

DRWD FIG. 42 is a diagram of **ATM** connections in the first case of the datagram delivery to external network shown in FIG. 40.

DRWD FIG. 46 is a diagram of **ATM** connections in the second case of the datagram delivery to external network shown in FIG. 45.

DRWD FIG. 48 is a diagram of **ATM** connections in the second case of the datagram delivery to external network shown in FIG. 47.

DRWD FIG. 49 is a schematic overall network diagram of the **ATM** communication system according to the present invention in a case of a large scale network architecture.

DRWD FIG. 52 is a diagram of **ATM** connections for an exemplary data transmission in a first case of the datagram delivery to external network shown in the network of FIG. 50.

DRWD FIG. 53 is a diagram of **ATM** connections for another exemplary data transmission in a first case of the datagram delivery to external network shown in the network of FIG. 50.

DRWD FIG. 54 is a diagram of **ATM** connections for an exemplary data transmission in a second case of the datagram delivery to external network shown in the network of FIG. 50.

DRWD FIG. 55 is a diagram of **ATM** connections for another exemplary data transmission in a second case of the datagram delivery to external network shown in the network of FIG. 50.

DRWD FIG. 56 is a schematic network diagram of the **ATM** communication system according to the present invention for one embodiment In a case of a modified network layer topology.

DRWD FIG. 61 is a schematic network diagram of another network configuration in the **ATM** communication system according to the present invention in a case of a modified network layer topology.

DRWD FIG. 62 is a schematic network diagram of the **ATM** communication system according to the present invention for an execution

of a routing protocol in a case of a modified network layer topology.

DRWD FIG. 64 is a schematic network diagram of the **ATM** communication system according to the present invention for a transmission of a routing data in a case of a modified network layer topology.

DRWD FIG. 65 is a schematic network diagram of another configuration of the **ATM** communication system according to the present invention for one embodiment in a case of a modified network layer topology.

DRWD FIG. 67 is a schematic network diagram of the **ATM** communication system according to the present invention for another embodiment in a case of a modified network layer topology.

DRWD FIG. 68 is a schematic diagram of one **ATM** connection setting in the **ATM** communication system according to the present invention for another embodiment in a case of a modified network layer topology.

DRWD FIG. 69 is a schematic diagram of another **ATM** connection setting in the **ATM** communication system according to the present invention for another embodiment in a case of a modified network layer topology.

DRWD FIG. 71 is a schematic diagram of one configuration of the **ATM** communication system according to the present invention for carrying out the broadcast in a case of a modified network layer topology.

DRWD FIG. 72 is a schematic diagram of another configuration of the **ATM** communication system according to the present invention for carrying out broadcast in a case of a modified network layer topology.

DETD **ATM** NETWORK BLOCK CONFIGURATION

DETD The **ATM** communication system according to the present invention can be constructed from one or more of the following **ATM** network blocks.

DETD 1. The first type **ATM** network block

DETD FIG. 1 shows a first type **ATM** network block in the **ATM** communication system according to the present invention, which comprises a first **ATM**-LAN 11 and a second **ATM**-LAN 12 which are connected through an IWU (inter-networking unit) 13, where each of the first **ATM**-LAN 11 and the second **ATM**-LAN 12 is a local area network formed by a plurality of terminals and nodes operated by the **ATM** scheme and equipped with a connection-less service function processing unit (CLSF) 14 or 15, respectively.

DETD In this **ATM** network block of FIG. 1, each **ATM**-LAN has an independent address assignment policy within itself. Namely, the right to determine VPI/VCI used within each **ATM**-LAN are assigned to a VPI/VCI determination function provided within each **ATM**-LAN, and this right is assigned independently for each **ATM**-LAN.

DETD In a case of a presence of a data to be transmitted, regardless of whether the destination of the data is within the same **ATM**-LAN or not, a terminal and nodes within each **ATM**-LAN transmits that data within the **ATM**-LAN by loading that data in an **ATM** cell and attaching an appropriate **ATM** cell header.

DETD In this **ATM** network block of FIG. 1, the IWU 13 has a detailed internal configuration as shown in FIG. 2 which comprises: an add/drop processing unit 21 provided on a cell transmission path 20, a multiplexer/demultiplexer (MUX/DEMUX) 22 having its output connected with the add/drop processing unit 22, a call processing unit 24 and an IWU management unit 25 which are connected with inputs of the MUX/DDEMUX 22, and an **ATM** cell header conversion unit 26 also provided on the cell transmission path 20. Here, this IWU 13 is located between the two **ATM**-LANs 11 and 12 and functions to control the inter-networking (inter-LAN connection) between these two **ATM** -LANs 11 and 12.

DETD The add/drop processing unit 21 looks up the header portion of the **ATM** cell entering to it, and in a case that cell has the appropriate header value, i.e., in a case that cell is a cell to be terminated within the IWU 13, it executes the processing for dropping that cell to the DEMUX 22 side, and the processing for adding the cell from the MUX 22 side onto the cell transmission path 20. Here, the add/drop processing unit 21 in this **ATM** network block of FIG. 1 is capable of adding or dropping the cell to either one of the right and left directions of the cell transmission path 20.

DETD The call processing unit 24 has basic functions for setting up, cutting off, changing, and managing the **ATM** connection over the IWU 13. In addition, this call processing unit 24 may also has additional functions for managing the bandwidth of the **ATM** connection or the cell transmission path 20 within the IWU 13.

DETD The **ATM** cell header conversion unit 26 looks up the header value of the cell entering to it, and in a case the header value is an appropriate value, it rewrites this header value (input cell header value) to another value (output cell header value). For this purpose, the **ATM** cell header conversion unit 26 has a correspondence table registering the input cell header values and the output cell header values in correspondence. This correspondence table is also initialized and managed by the IWU management unit 25. As this correspondence table contains the input cell header value which is also registered in the drop table mentioned above, the correspondence table and the drop table can be unified together into a single table easily.

DETD In this IWU 13, the modules are connected with each other through a bus line (not shown), and the control from the IWU management unit 25 such as the changing of the setting value at each module is achieved through this bus line. Alternatively, the data exchange among the modules may be achieved by loading the data to be exchanged into the **ATM** cell and exchanging the **ATM** cell among the modules, instead of using the bus line, if desired.

DETD Also, the **ATM** cell header conversion unit 28 may be provided on both of the right and left sides of the add/drop processing unit 21 in order to handle the **ATM** cell header conversion for the **ATM** cell flow in the right and left directions of the cell transmission path 20 separately. Alternatively, the add/drop processing unit 21 may be provided on both of the right and left sides of the **ATM** cell header conversion unit 26 in order to handle the add/drop processing for the **ATM** cell flow in the right and left directions of the cell transmission path 20 separately. In these cases, the functions of the IWU 13 can be made to appear symmetrical for the right and left directions of the cell transmission path 20.

DETD In this **ATM** network block of FIG. 1, the CLSF 14 (15) realizes the connection-less service function in which the datagram delivered over the IWU 13 is terminated once, and after the network layer address is looked up, the datagram is transmitted to the appropriate **ATM** connection. Thus, the **ATM** connection for the datagram delivery is terminated once at the CLSF 14 (15), but there is no need to re-assemble the datagram. That is, at the CLSF 14 (15), it is not necessary to make the network layer termination, and it suffices to make the connection-less (CL) layer termination as considered by the CCITT. In this case, the appropriate **ATM** connection to which the datagram is transmitted from the CLSF 14 (15) is the VP/VC connected with the terminal/node having the looked up network layer address, or the VP/VC connected with the other CLSF which is expected to have the function of the datagram delivery to the looked up network layer address.

DETD 2. The second type **ATM** network block

DETD FIG. 3 shows a second type **ATM** network block in the **ATM** communication system according to the present invention, which comprises a first **ATM**-LAN 131, a second **ATM**

-LAN 132, and a third **ATM**-LAN 133 which are connected through an IWU (inter-networking unit) 134, where each of the first **ATM**-LAN 131, the second **ATM**-LAN 132, and the third **ATM**-LAN 133 is a local area network formed by a plurality of terminals and nodes operated by the **ATM** scheme and equipped with a connection-less service function processing unit (CLSF) 135, 136, or 137, respectively.

DETD In this **ATM** network block of FIG. 3, similarly to the first type **ATM** network block of FIG. 1 described above, each **ATM**-LAN has an independent address system within itself, and in a case of a presence of a data to be transmitted, regardless of whether the destination of the data is within the same **ATM**-LAN or not, a terminal and nodes within each **ATM**-LAN transmits that data within the **ATM**-LAN by loading that data in an **ATM** cell and attaching an appropriate **ATM** cell header.

DETD In this **ATM** network block of FIG. 3, the IWU 134 has a detailed internal configuration as shown in FIG. 4 which comprises: an **ATM** switch 141 of N inputs and M outputs (N=M=2 in FIG. 4), a call processing unit 143, an IWU management unit 144, input processing units 14A and 14B for entering inputs from two other **ATM**-LANs, and output processing units 14X and 14Y for outputting outputs to two other **ATM**-LANs, where the **ATM** switch 141 switches the outputs of the input processing units 14A and 14B, the call processing unit 143, and the IWU management unit 144 into the inputs of the output processing units 14X and 14Y, the call processing unit 143, and the IWU management unit 144. In a general case of having more than three **ATM**-LANs, this IWU 134 can be expanded by incorporating more than two input processing units and the output processing units, and functions to control the inter-networking (inter-LAN connection) among these **ATM**-LANs.

DETD Each of the input processing units 14A and 14B has functions to analyze the header value such as VPI/VCI value of the **ATM** cell entering to it, carry out the conversion of the header value if necessary, and attaching a routing tag for enabling an appropriate routing of the cell at the **ATM** switch 141.

DETD The **ATM** switch 141 then carries out the routing of the cell entered from the input processing unit 14A or 14B according to the routing tag attached to the cell. In addition, the **ATM** switch 141 may also have the functions such as the broadcast function or the multicast function if desired.

DETD Each of the output processing units 14X and 14Y has functions to remove the routing tag from the cell outputted from the **ATM** switch 141, and carries out the conversion of the reader value if necessary. This latter **ATM** cell header conversion function is a function required to be provided either at the input processing unit or the output processing unit such that a set of the input processing unit and the output processing unit can control the connection with respect to the switching nodes and terminals within the neighboring **ATM**-LAN, or even to the IWU 134 if necessary.

DETD The call processing unit 143 has basic functions for setting up, cutting off, changing, and managing the **ATM** connection over the IWU 134, similarly to the call processing unit 24 in the configuration of FIG. 1 described above.

DETD In this IWU 134, the modules are connected with each other through a bus line (not shown), and the control from the IWU management unit 144 such as the changing of the setting value at each module is achieved through this bus line. Alternatively, the data exchange among the modules may be achieved by loading the data to be exchanged into the **ATM** cell and exchanging the **ATM** cell among the modules, instead of using the bus line, if desired.

DETD In this **ATM** network block of FIG. 3, the CLSF 135 (136, 137) realizes the connection-less service function similar to that realized

by the CLSF 14 (15) in the configuration of FIG. 1 described above.

DETD When the ATM communication system according to the present invention is constructed by connecting a plurality of the **ATM** network blocks as described above, each **ATM**-LAN can be regarded as a sub-network. Here, a scheme for the datagram delivery between terminals within such a sub-network will be described.

DETD 1. General **ATM** network

DETD In an exemplary sub-network 410 shown in FIG. 5 which is equipped with the **address resolution server** (ARS) 413 and the CLSF 414 and which is connected with the external network 416 through the IWU 415, one procedure for the datagram delivery from a terminal (TE) 411 to another terminal 412 can be carried out as follows.

DETD Namely, when a datagram transmission request occurs at the terminal 411, the terminal 411 makes an **address resolution** (AR) request for obtaining a suitable **ATM** address for the datagram transmission to a destination terminal 412 with respect to the ARS 413 through an **ATM** connection 41A.

DETD In response, the ARS 413 notifies an **address resolution** (AR) response indicating VCI/VPI data or **ATM** address (as defined by the **ATM** Forum) to be attached to the datagram at the terminal 411 which are identifiers of an appropriate **ATM** connection for the datagram transmission to the destination terminal 412, through an **ATM** connection 41B to the terminal 411.

DETD When this AR response is received at the terminal 411, the notified VCI/VPI are attached to the datagram and the datagram is outputted to the network. The outputted datagram is then directly delivered to the destination terminal 412 through an **ATM** connection 41C specified by the attached VCI/VPI of the datagram.

DETD In this case, there is a need to provide full meshed **ATM** connections among all the terminals within each sub-network. If **ATM** address is replied by ARS, the terminal will establish **ATM** connection for the destination terminal using the informed **ATM** address.

DETD In this procedure, the AR request can be made either whenever the datagram transmission request has occurred, or only when an appropriate address data for the destination terminal cannot be found in an **address resolution** (AR) table provided in the terminal 411 which is a cache memory for the destination targets. In the latter case, when the address of the destination terminal can be found in the AR table, the procedure for making the AR request and receiving an **address resolution** (AR) response from the ARS 413 can be omitted.

DETD Also, in this case, the terminal 411 carries out the protocol according to the flow chart of FIG. 7, in which after the datagram transmission request occurs at the step 431, whether the **address resolution** is possible by using the AR table of this terminal 411 or not is checked at the step 432. If so, the datagram transmission takes place immediately at the step 433, whereas otherwise the AR request is made to the ARS 413 at the step 434, the AR response is received from the ARS 413 at the step 435, and then the datagram transmission takes place at the step 436.

DETD It is to be noted here that the exchange of the AR request and the AR response can be realized by using the point-to-point **ATM** connections as shown in FIG. 5, or by using a broadcast channel.

DETD Namely, this is a case in which the actual datagram transmission is carried out by the CLSF 414. In this case, when a datagram transmission request occurs at the terminal 411, the terminal 411 carries out the **address resolution** to obtain the **ATM** connection data for the datagram transmission to the destination terminal 412 according to the AR table provided in this terminal 411. In a case the address data for the destination terminal 412 cannot be found

in the AR table at the terminal 411, the terminal 411 makes the AR request for obtaining a suitable **ATM** address for the datagram transmission to a destination terminal 412 with respect to the ARS 413 through an **ATM** connection 41A.

DETD In response, in a case the destination terminal is a terminal in this sub-network 410, the ARS 413 notifies the AR response indicating **ATM** layer address data through an **ATM** connection 41B to the terminal 411. A case in which the destination terminal is not a terminal in this sub-network 410 will be described below.

DETD When the **address resolution** is completed, the terminal 411 attaches the appropriate VCI/VPI either obtained from the AR table or the AR response to the cell for transmitting the datagram and the cell is outputted to the network. Here, the attached VCI/VPI
are
the identifiers of an **ATM** connection 441 from the terminal 411 to the CLSF 414, so that the outputted cell reaches to the CLSF 414 through this **ATM** connection 441. At the CLSF 414, the address data of the received datagram is analyzed, and the VCI/VPI of an **ATM** connection 442 for transmitting the datagram to the destination terminal 412 are attached to the cell, and the cell is outputted to the network. The outputted cell then reaches to the destination terminal 412 through the **ATM** connection 442.

DETD In this alternative procedure, there is a need to provide star-shaped **ATM** connections from the CLSF 414 to all the terminals. Also, the exchange of the AR request and the AR response can be realized by using the point-to-point **ATM** connections as shown in FIG. 8, or by using a broadcast channel.

DETD Here, the **address resolution** procedure at the ARS 413 can be realized by the search on the address space data (address mask) of the network. Namely, as will be described below, it suffices for the ARS 413 to analyze the network address space in which the destination terminal is present, even for the destination terminal in the external network 416, and there is no need to resolve the VCI/VPI data for making a direct access through the **ATM** connection to the destination terminal.

DETD In this case, each network element of the sub-network 410 is assigned with VPI as indicated in FIG. 10. Here, each terminal/**server** is equivalent to have a multipoint-to-point **ATM** connection from all UNI (User Network Interface) points within the sub-network
410.
In other words, when the cell attached with the VPI of the destination terminal is outputted to the network from one terminal, the cell is transmitted to the destination UNI point. For example, in order to transmit the cell to the ARS 413, the VPI to be attached to the cell is VPI.sub.413 assigned to the ARS 413.

DETD In this case, the procedure similar to that shown in FIG. 5 described above can be realized by using the connections 46A, 46B, and 46C. Namely, the terminal 411 transmits the AR request cell with the VPI
data
of the VPI.sub.413 to the ARS 413. Here, the ARS 413 can recognize that the received cell is transmitted from the terminal 411 according to the VCI data or the upper layer identifier. For example, when the VPI data of the VPI1.sub.411 assigned to the terminal 411 is written in the VCI field, the ARS 413 can recognize that the cell from the terminal 411 by the **ATM** header. Alternatively, the VCI data can be the identification number for positively identifying the cell as the AR request cell for the datagram transmission.

DETD Then, the ARS 413 carried out the **address resolution** for the destination terminal 412, and writes VPI=VPI.sub.411 in the AR response cell and outputs the AR response cell to the network. Just as in the ARS 413, the terminal 411 then recognizes that the received cell is the AR response cell according to the VCI data or the upper layer header data. Here, the AR response cell at least contains VPI.sub.412 which is the access address data for the terminal 412.

DETD On the other hand, the procedure similar to that shown in FIG. 8

described above can be realized by using the connections 46A, 46B, 46D, and 46E. Namely, the terminal 411 transmits the AR request cell with the VPI data of the VPI.sub.413 to the ARS 413. Then, the ARS 413 carried out the **address resolution** for the destination terminal 412, and writes VPI=VPI.sub.414 in the AR response cell and outputs the AR response cell to the network. Here, the AR response cell at least contains VPI.sub.414 which is the access address data for the CLSF 414. Also, the CLSF 414 can recognizes that the received cell is the cell for the datagram transmission from the terminal 411 according to an identification data which is either the VCI data or the upper layer header data, and this identification data may be notified from the ARS 411 to the terminal 411 as the data content of the AR response.

DETD The CLSF 414 then analyzes the address data of the received cell, and attaches the VPI=VPI.sub.412 for transmitting the datagram cell to the terminal 412 and outputs the cell to the network. Then, the cell is transmitted to the terminal 412 through the **ATM** connection 46E.

DETD 1. General **ATM** network: Scheme I

DETD In this case, an exemplary hierarchical network architecture is as shown in FIG. 11 which comprises networks 471 to 475 with the inter-networking provided by the IWUs 476 to 479, including a public network 475 connected with the network 471 through an IWU 479. Here, each of the IWUs 476 to 479 can realize the relaying of the **ATM** cells without terminating the **ATM** connection, by having a function to convert the VCI/VPI of the received cell into VCI/VPI assigned to the corresponding **ATM** connection in the neighboring network.

DETD FIG. 12 shows the setting of the **ATM** connections related to the **address resolution** in which the networks 471 to 474 are also equipped with the ARSs 481 to 484, respectively, each for managing the address data of the terminals or the network itself for at least one of the networks 471 to 474 to which each of which belongs, where the ARS 481 is connected with the ARSs 482 to 484 through the **ATM** connections 485 to 487.

DETD FIG. 13 shows the setting of the **ATM** connections 496, 497, 498, and 49B required for transmitting the datagrams from the network 472 to the other networks 471, 472, 474, and 475, respectively, where the **ATM** connections 486, 487, and 498 are single direction **ATM** connections from the IWU 476 of the network 472 to the CLSFs 491, 493, and 494, respectively, while the **ATM** connection 49B is an **ATM** connection to a CLSF (not shown) of the public network 475 which is usually set to be bidirectional. Although not shown in FIG. 13, the similar bidirectional **ATM** connection from each of the other networks 471, 473, and 474 to the public network 475 are also provided. Here, any of the CLSFs and the ARSs can be located at positions of the corresponding IWUs if desired. Also, each corresponding CLSF and ARS can be located at the identical position.

DETD For the connection-less communication cell to be transmitted from the public network 475 to any of the networks 471 to 474, there is provided a **server** (not shown) for terminating the connection-less communication (**ATM** connection) to the public network 475 once within the network 471, such that from the public network 475 side, this **server** is defied as the access point for the connection-less communication. This **server** terminates the **ATM** connection and then transmits the datagram to the destination terminal. Here, the datagram transmission from this **server** is the same as the datagram transmission from each terminal to the other terminal.

DETD (1) The terminal makes the AR request. This can be done either always or

only in a case the **address resolution** cannot be succeeded by the terminal itself such as a case in which a suitable entry is present in the AR table.

DETD (2) The terminal obtains the VCI/VPI data, which is the identifier of the **ATM** connection, provided from the ARS in order to make access to the destination terminal.

DETD Here, at a time of the datagram transmission, there is no need for the terminal to carry out the procedure for setting up a particular connection defined in the **ATM** network.

DETD In this case, the star-shaped **ATM** connections (bidirectional communication channels) have been established from the ARS 481 in the network 471 to the ARSs 482 to 484 in the networks 472 to 474, respectively. For example, in order to obtain the VCI/VPI for transmitting the datagram from the terminal 47A to the terminal 47D, the terminal 47A transmits the AR request cell having the address data of the terminal 47D to the ARS 482 of its own network 472. The ARS 482 which received this AR request cell then recognizes that the address of the destination terminal written in the received cell does not belongs to its own network 472, and carries out the relaying of the AR request cell through the already set up **ATM** connection 485 to the ARS 481 in the network 471. Alternatively, it is also possible for the ARS 482 to cache the network address data of the external network previously obtained and the VCI/VPI data for transmitting the cell to the corresponding CLSF through the **ATM** connection 485 in advance.

DETD Here, the **address resolution** at the ARS 481 is carried out as follows. Namely, the ARS 481 has the address data (address space data such as net/ID) of the terminals contained in its own network 471 and the address space data for the sub-networks 472 to 474. Then, the ARS 481 analyzes the transmission target network by comparing the address written in the received AR request cell with the address space data for each sub-network. Here, at a time of this comparison, it is not necessary for the ARS 481 to analyze the host address of the destination address, and it suffices to analyze only up to the network address.

DETD In this manner, the ARS 481 possesses the addresses and the address space data of the terminals belonging to the network 471 and the sub-networks 472. 473, and 474, so as to carry out the **address resolution**.

DETD The address data (**ATM** layer address data) received by the ARS 482 from the ARS 481 is the data indicating the identifier (normally VCI/VPI, but may contain the identification data for the upper layer) of the **ATM** connection to the CLSF in the target sub-network from the IWU 476. For example, at a time of the datagram transmission from the terminal 47A to the terminal 47D, the identifiers of the **ATM** connections 495 and 497 for accessing the CLSF 494 are notified as the AR response, whereas at a time of the datagram transmission from the terminal 47A to the terminal 47F, the identifiers of the **ATM** connections 495 and 496 for accessing the CLSF 491 are notified as the AR response. Here, the ARS 482 notifies the VCI/VPI data for correctly relaying the **ATM** connection at the IWU 476 to the terminal 47A, according to the VCI/VPI data received from the ARS 481. The VCI/VPI data notified to the terminal 47A is then rewritten into the other VCI/VPI at the IWU 476.

DETD In this case, the star-shaped **ATM** connections as shown in FIG. 12 described above is formed from the ARS 481 in the network 471 to the ARSs 482 to 484 in the networks 472 to 474, respectively, or the meshed **ATM** connections as shown in FIG. 16 is formed by the ARSs 481 to 484. Each ARS obtains the address space data and the **ATM** connection data (VCL/VPI) for the external sub-networks viewed from its own sub-network using the **ATM** connections defined as shown in FIG. 12 or FIG. 16. Here, FIG. 12 is in a form in which the ARS 481 functions as a master ARS, while FIG. 16 is in a distributed form in

which each ARS operates independently. In a case the number of hierarchical levels in the network is at most three, a case of FIG. 12 to make the backbone network as the master is more appropriate.

DETD Here, the **address resolution** at the ARS 482 is carried out as follows. Namely, the ARS 482 has the address data (address space data) of the terminals contained in its own network 472 and the address space data for the sub-networks 471, 473, and 474. Then, the ARS 482 analyzes the transmission target network by comparing the address written in the received AR request cell with the address space data for each sub-network. Here, at a time of this comparison, it is not necessary for the ARS 482 to analyze the host address of the destination address, and it suffices to analyze only up to the network address.

DETD In this manner, the ARS 482 possesses the addresses and the address space data of the terminals belonging to the network 472 and the sub-networks 471, 473, and 474, so as to carry out the **address resolution**.

DETD The address data (**ATM** layer) received by the ARS 482 from the other ARS is the data indicating the identifier (normally VCI/VPI, but may contain the identification data for the upper layer) of the **ATM** connection to the CLSF in the target sub-network from the IWU 476. For example, at a time of the datagram transmission from the terminal 47A to the terminal 47D, the identifiers of the **ATM** connections 495 and 497 for making an access to the CLSF 494 are notified as the AR response, whereas at a time of the datagram transmission from the terminal 47A to the terminal 47F, the identifiers of the **ATM** connections 495 and 496 for making an access to the CLSF 491 are notified as the AR response. Here, the ARS 482 notifies the VCI/VPI data for correctly relaying the **ATM** connection at the IWU 476 to the terminal 47A, according to the VCI/VPI data received from the other ARS. The VCI/VPI data notified to the terminal 47A is then rewritten into the other VCI/VPI at the IWU 476.

DETD Among ARSs, not only the address space data exchange protocol for each sub-network, but also the routing protocol concerning the datagram transmission (connection-less communication) among the sub-networks is also operated. More specifically, this routing protocol carries out the management of the **ATM** connection setting between the IWU and the CLSF as shown in FIG. 13 described above. Here, the individual **ATM** connection is separated at the IWU (i.e., closed within the sub-network), and the **ATM** connection routing control and the **ATM** connection management (such as VCI/VPI management) are made by the other **ATM** connection **server** process and the routing **server** process, and the ARS exchanges the control messages with these **servers** as well as the IWU to carry out the management of the **ATM** connections necessary for the connection-less communication.

DETD There is also a case requiring the use of the **ATM** connection having different route from the normally used **ATM** connection due to the congestion or the obstruction in the sub-network. In such a case, the routing control process for carrying out the management control of the VCI/VPI to be set up in the table of each switch as well as the routing table data (where the control process for carrying out the address management can be the other process) carries out the management control such that the VCI/VPI the same VCI/VPI to be shows to the UNI can be maintained even when the route within the sub-network is changed.

DETD Next, when the access point of the various **server** such as CLSF is moved, it suffices to reboot it such that the connection identifiers (VCI/VPI) visible from each access point becomes the same. Also, at a time of the reboot, with respect to the related access point, the

request message for discarding the data for the old access from the AR table is transmitted along with the new access data if necessary. In the latter case, there is a need for the IWU to update the entry data in the table of FIG. 19, either according to the data within the transmitted message or by executing the protocol for obtaining the new data.

DETD Thus, it suffices for each CLSF to possess only the address data of the terminals of the network to which that CLSF itself belongs. When the address of the received datagram is present in its own network, the appropriate **ATM** connection is selected and the relaying of the datagram is carried out.

DETD An exemplary protocol processing in a case of transmitting the datagram from the terminal 47A to the terminal 47D is shown in FIG. 20. Namely, the **ATM** connection is terminated at the CLSF 494 once, i.e., the protocol of the OSI layer 3 is terminated at the CLSF 494. The OSI layer 3 protocol processing is carried out at the CLSF 494, and the data unit is transmitted to the terminal 47D using the **ATM** connection. In this manner, at a time of the datagram transmission to the terminal other than those of its own sub-network, the end-to-end datagram delivery can be realized with only one **ATM** connection termination.

DETD In this case, the **address resolution** is carried out as follows.

DETD In transmitting the datagram from the terminal 47A to the terminal 47D, when the terminal 47A does not possess the **ATM** layer address data for transmitting the datagram to the terminal 47D, the terminal 47A transmits the AR request cell having the address data of the terminal 47D to the ARS 482 through the **ATM** connection 571 (581). Here, the **ATM** connection 571 (581) can be realized by either the point-to-point connection or the broadcast connection. The ARS 482 which received the AR request cell recognizes that the address requested by the AR request cell does not belongs to its own network 472, so that in the situation of FIG. 21, the ARS 482 transmits the AR request cell to the ARS 481 through the **ATM** connection 572. Here, the procedure for the ARS 482 to receive the AR request cell and then transmit the AR request cell to the ARS 481 can be any of the following.

DETD (1) In a case the ARS is responsible for responding to all the AR request cells generated within its network, the ARS carries out the screening of the AR request cells first. Namely, whether the address in the received cell is the element of the address space of its own network or not is checked by using the network mask, etc.. If the address belongs to its own network, the address table is looked up and the **ATM** layer address data for the appropriate terminal is returned. On the other hand, when the address does not belongs to its own network, the AR request cell is transmitted to the prescribed superior ARS which is the ARS 481 in the example of FIG. 21.

DETD (2) In a case the ARS makes the response only to the request for transmitting the datagram to the terminal belonging to the sub-network other than its own network, and the response to the AR request for the terminal within its own network is returned by the terminal to which the datagram is to be transmitted itself, the result differs for a case of using the broadcast channel and a case of using the point-to-point connection at a time of the **address resolution**. In a case of using the broadcast channel, after the screening of the address is carried out, the AR request cell is taken and transmitted to the superior ARS. On the other hand, in a case of using the point-to-point connection, the AR request cell is transmitted to the superior ARS

unconditionally in principle.

DETD In the example of FIG. 22, the ARS 481 which received the AR request cell checks if the address in the AR request cell is contained in the addresses and the address space contained in its own network. In a case the corresponding address is not present in the address entries, it is judged as the address directed to the public network. In this example, the destination terminal is the terminal 47D, so that the ARS 471 recognizes that the address in the AR request cell is present in the address space of its own network 474 and therefore the address space data possessed by the network 474 can be used. The ARS 481 which analyzed the address of the terminal 47D returns the response indicating the VCI/VPI data of the **ATM** connection from the IWU 476 to the CLSF 494 (VCI/VPI data viewed from the IWU 476) to the ARS 482.

DETD The ARS 482 then returns the VCI/VPI data which is the identification data of the **ATM** connection to be relayed to the **ATM** connection connected to the CLSF 494 at the IWU 476 to the terminal 47A. By using this VCI/VPI, the terminal 47A can deliver the datagram directly to the CLSF 494.

DETD In the example of FIG. 22 in which the ARS 482 can make the **address resolution** by itself, with respect to the AR request given through the **ATM** connection 581, the AR response can be directly transmitted to the terminal 47A through the **ATM** connection 582.

DETD The terminal 47A transmits the cell having the datagram information to the CLSF 494 through the **ATM** connection 575 (583). The IWUs 476 and 478 carries out the relaying of the **ATM** connection by rewriting the VCI/VPI data of the received cell. This processing is carried out as the **ATM** layer processing without raising it to the upper layer, so that the **ATM** connection 575 (583) passing through the IWUs 476 and 478 can be regarded as one **ATM** connection without the **ATM** terminal point.

DETD At the CLSF 494 which is the terminal point of the **ATM** connection 575 (583), the network layer processing is carried out. The CLSF 494 carries out the analysis of the network address, and the datagram is relayed to the **ATM** connection 576 (584) and transmitted to the terminal 47D.

DETD In this manner, there are only two **ATM** connections from the terminal 47A to the CLSF 494, and from the CLSF 494 to the terminal 47D, so that they are terminated only once.

DETD In this case, the **ATM** layer address assignment method will be described first.

DETD In this case, the **ATM** connections are set up such that the setting of the **ATM** connections related to the **address resolution** are as shown in FIGS. 23 to 25. Here, each of the ARS 481 to 484 is managing the address data for the terminals or the network contained in at least one of the networks 471 to 474 to which it belongs.

DETD FIG. 23 is a case of managing the address data of each sub-network with the ARS 481 playing the leading role (of a root ARS). The VCI/VPI data are rewritten by the IWU and the relaying of the **ATM** connections is carried out. For example, the **ATM** connection from the ARS 482 to the ARS 481 is formed by the connections 591 and 592. The connection 591 has the VPI-F having VPI.sub.476-2 which is the access address (VPI) of the IWU 476 for the network 472, and the VCI-F1 having VPI.sub.482 which is the access address of the ARS 482. As for the VCI-F2, it can take an arbitrary value in principle, but it is coded such that the IWU 476 can identify the received cell as that which is to be relayed to the connection 592 from the data content of the VCI-F2. On

the other hand, the connection 592 has the VPI-F having VPI.sub.481 which is the access address of the ARS 481, and the VCI-F1 having VPI.sub.476-1 which is the access address of the IWU 476 for the network 471. Here, in both of these connections 591 and 592, the VCI-F2 can take an arbitrary value in principle.

DETD The IWU 476 analyzes the VCI/VPI data to be written into the cell of the connection 592 from a set of data VCI-F1 and VCI-F2 of the received cell. Therefore, the IWU 476 has the 16 bits VCI field as the table entry, and as a result, has the function to analyze the VCI/VPI data. The VPI-F of the cell of the connection 592 is analyzed by the combination of VCI-F1 and VCI-F2. To the VCI-F1, VPI.sub.476-1 is written, while the VCI-F2 is coded as the identifier of the **ATM** connection between the ARS 482 to the ARS 481. The value of the VCI-F2 is determined at a time of setting the **ATM** connections (connections 591 and 592). The assignment of the VCI-F2 can be made by the process for managing the VCI-F2 within the sub-networks (networks 471 and 472), or by the process for managing the value of the VCI-F2 at the terminals (ARS 481 and IWU 476).

DETD For example, the **ATM** connection 617 from the ARS 482 to the ARS 484 is formed by the connections 6021, 6041, and 6061. The connection 6021 has the VPI-F having VPI.sub.476-2 which is the access address of the IWU 476 for the network 472, and the VCI-F1 having VPI.sub.482 which is the access address of the ARS 482. The VCI-F2 is an identification number allocated to this connection 6021 such that this connection 6021 can be identified by the combination of the VCI-F1 and the VCI-F2. The connection 6061 has the VPI-F having VPI.sub.478-1 which is the access address of the IWU 478 for the network 471, and the VCI-F1 having VPI.sub.476-1 which is the access address of the IWU 476 for the network 471. The VCI-F2 is a value set at a time of setting this connection 6061. The connection 6041 has the VPI-F having VPI.sub.484 which is the access address of the ARS 484, and the VCI-F1 having VPI.sub.478-1 which is the access address of the IWU 478 for the network 471. The VCI-F2 is a value set at a time of setting this connection 6041.

DETD For example, the IWU 478 analyzes the VCI/VPI data to be written into the cell of the connection 6041 from a set of data VCI-F1 and VCI-F2 of the received cell. Therefore, the IWU 478 has the 16 bits VCI field as the table entry, and as a result, has the function to analyze the VCI/VPI data. The VPI-F of the cell of the connection 6041 is analyzed by the combination of VCI-F1 and VCI-F2. To the VCI-F1, VPI.sub.478-1 is written, while the VCI-F2 is coded as the identifier of the **ATM** connection between the ARS 482 to the ARS 481 by the analysis of the VCI field data. The value of the VCI-F2 is determined at a time of setting the **ATM** connections (connections 6021, 6041, and 6061). The assignment of the VCI-F2 can be made by the process for managing the VCI-F2 within the sub-networks (networks 471 472, and 474), or by the process for managing the value of the VCI-F2 at the terminals (ARS 481, IWU 476, and ARS 484).

DETD By the setting scheme of the VCI/VPI field as in the above, even when the ARS has transmitted the data over a plurality of cells to the other ARS, the re-assembling of the data at the receiving side can be done without any problem. Here, for the data identification such as which terminal has the data transmitted from or whether the data is related to the **address resolution** protocol, there is a need to use the upper layer identification field.

DETD FIG. 28 shows the setting of the **ATM** connections required for transmitting the datagram from the terminal 47A to the terminal 47F, the public network 475, and the terminal 47D. Here, the datagram transmission can be carried out in either one of the following two schemes.

DETD In this case, two **ATM** connections are required. One is formed by the connections 621 and 624 between the terminal 47A and the CLSF 491, while the other is formed by the connection 625 between the CLSF 491 and the terminal 47F. The terminal 47A transmits to the IWU 476 the cell with the VPI-F having VPI.sub.476-2 which is the access address of the IWU 476 for the network 472, the VCI-F1 having the VPI.sub.47A which is the access address of the terminal 47A, and the VCI-F2 having a value set at a time of setting the connection 621. The IWU 476 analyzes the VCI of the received cell, as well as the corresponding VPI-F and the VCI-F2. Then, to the VCI-F1, VPI.sub.476-1 which is the access address of the IWU 476 for the network 471 is written. Here, the VCI-F2 is a value which is determined at a time of setting the connection 624, which can be written by copying the value of the VCI-F1 of the cell received by the IWU 476, i.e., the VPI.sub.47A which is the access address of the terminal 47A.

DETD The datagram arrived at the CLSF 491 is cell re-assembled once, and the **ATM** connection is terminated. The CLSF 491 analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 47F. Then, the CLSF 491 generates the cell with the VPI-F having VPI.sub.47F which is the access address of the terminal 47F, the VCI-F1 having the VPI.sub.491 which is the access address of the CLSF 491, and the VCI-F2 having an identification number assigned to the connection 625, and transmits the datagram to the terminal 47F. Here, the terminal 47F can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 47F.

DETD In this case, only one **ATM** connection formed by the connections 622, 626, and 627 between the terminal 47A and the public network 475 is required. The terminal 47A transmits to the IWU 476 the cell with the VPI-F having VPI.sub.476-2 which is the access address of the IWU 476 for the network 472, the VCI-F1 having the VPI.sub.47A which is the access address of the terminal 47A, and the VCI-F2 having a value set at a time of setting the connection 622. The IWU 476 analyzes the VCI of the received cell, as well as the corresponding VPI-F and the VCI-F2. Then, to the VCI-F1, VPI.sub.476-1 which is the access address of the IWU 476 for the network 471 is written. Here, the VCI-F2 is a value which is determined at a time of setting the connection 626, which can be written by copying the value of the VCI-F1 of the cell received by the IWU 476, i.e., the VPI.sub.47A which is the access address of the terminal 47A. The IWU 479 writes the VCI/VPI assigned to the **ATM** connection 627 defined by the public network 475 according to the VCI data of the received cell, and transmits the cell to the public network 475.

DETD In this case, two **ATM** connections are required. One is formed by the connections 623, 628, and 629 between the terminal 47A and the CLSF 494, while the other is formed by the connection 62A between the CLSF 494 and the terminal 47D. The terminal 47A transmits to the IWU 476 the cell with the VPI-F having VPI.sub.476-2 which is the access address

of the IWU 476 for the network 472, the VCI-F1 having the VPI.sub.47A which is the access address of the terminal 47A, and the VCI-F2 having a value set at a time of setting the connection 623. The IWU 476 analyzes the VCI of the received cell, as well as the corresponding VPI-F and the VCI-F2. Then, to the VCI-F1, VPI.sub.476-1 which is the access address of the IWU 476 for the network 471 is written. Here, the VCI-F2 is a value which is determined at a time of setting the connection 628, which can be written by copying the value of the VCI-F1 of the cell received by the IWU 476, i.e., the VPI.sub.47A which is the access address of the terminal 47A.

DETD The datagram arrived at the CLSF 494 is cell re-assembled once, and the **ATM** connection is terminated. The CLSF 494 analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 47D. Then, the CLSF 494 generates the cell with the VPI-F having VPI.sub.47D which is the access address of the terminal 47D, the VCI-F1 having the VPI.sub.494 which is the access address of the CLSF 494, and the VCI-F2 having an identification number assigned to the connection 62A, and transmits the datagram to the terminal 47D. Here, the terminal 47D can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 47D.

DETD In this scheme, each CLSF has obtained the VPI address, and all the connections identified by the obtained VPIs are **ATM** connections to be used for the cell transmission related to the datagram transmission (connection-less communication). Namely, the CLSF **server** requires the **ATM** connection (not connection-less one) in order for itself to carry out the communication with the other terminal/**server**. In other words, there is a need for the CLSF to obtain at least two access addresses (VPIs) at a time of the boot.

DETD By the scheme as in the above, in the procedure for the **address resolution** which precedes the datagram transmission, the terminal can transmits the datagram (one or more cells) as long as the identification number of the sub-network to which the destination terminal belongs. This datagram transmission will now be described in detail.

DETD The datagram arrived at the CLSF 491 is cell re-assembled once, and the **ATM** connection is terminated. The CLSF 491 analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 47F. Then, the CLSF 491 generates the cell with the VPI-F having VPI.sub.47F which is the access address of the terminal 47F, and transmits the datagram to the terminal 47F. Here, the CLSF 491 can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the CLSF 491. Therefore, it is also possible to carry out the pipeline type relaying of the datagram (cell).

DETD The IWU 476 analyzes the VCI of the received cell, as well as the corresponding VPI-F and the VCI-F2. For example, in a case the VCI-F1 has the VPI.sub.479 which is the access address of the IWU 479, the VPI-F of the cell to be outputted can be obtained by copying the VCI-F1 of the received cell. Then, to the VCI-F1, VPI.sub.476-1 which is the access address of the IWU 476 for the network 471 is written. Here, the VCI-F2 can be set to be transparent. Namely, in a case the VCI-F1 of the cell to be transmitted from the terminal 47A has VPI.sub.479, the relaying of the cell can be realized by the procedure of (1) copying the VCI-F1 of the received cell to the VPI-F of the transmission cell, (2)

copying the VCI-F2 of the received cell to the VCI-F2 of the transmission cell, and (3) writing VPI.sub[illegible]5-1 to the VCI-F1 of the transmission cell. The IWU 479 writes the VCI/VPI assigned to the **ATM** connection 627 defined by the public network 475 according to the VCI data of the received cell, and transmits the cell to the public network 475.

DETD The datagram arrived at the CLSF 494 is cell re-assembled once, and the **ATM** connection is terminated. The CLSF 494 analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 47D. Then, the CLSF 494 generates the cell with the VPI-F having VPI.sub.47D which is the access address of the terminal 47D, and transmits the datagram to the terminal 47D. Here, the terminal 47D can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 47D. More specifically, for example, the sub-network to which the transmission source terminal belongs can be determined from the VCI-F1, and the IWU which contains that sub-network can be determined from the VCI-F2 as the identification number of that sub-network.

DETD 3. General **ATM** network: Scheme II

DETD In this case, an exemplary hierarchical network architecture is as shown in FIG. 27 which comprises networks 631 to 635 with the inter-networking provided by the IWUs 636 to 639, including a public network 635 connected with the network 631 through an IWU 639. Here, each of the IWUs 636 to 639 can realize the relaying of the **ATM** cells without terminating the **ATM** connection, by having a function to convert the VCI/VPI of the received cell into VCI/VPI assigned to the corresponding **ATM** connection in the neighboring network.

DETD FIGS. 28 and 29 show the two settings of the **ATM** connections related to the **address resolution**, where the ARS 63G is connected with the ARSs 63D, 63E, and 63F through the **ATM** connections.

DETD FIG. 30 shows the setting of the **ATM** connections 641 to 646 required for transmitting the datagrams from the terminal 63A to the terminal 63C, the public network 635, and the terminal 63B, where the **ATM** connections 642, 644, and 645 are single direction **ATM** connections from the CLSF-O 63M to the CLSF-I G3L, the public network 635, and the CLSF-I 63J, respectively. Although not shown in FIG. 30, the similar **ATM** connections from each of the other sub-networks are also provided. In addition, the **ATM** connections among the CLSF-I and the CLSF-O as shown in FIG. 31 are also provided.

DETD Here, in a case of the connection-less communication from the public network 635 to the terminal belonging to the defined networks 631 to 634, the **ATM** connection related to the connection-less communication from the public network 635 is terminated at a **server** for terminating this **ATM** connection for the connection-less communication and relaying the datagram, which is provided in the network 631. The datagram is transmitted from this **server** to the destination terminal by the same procedure as described below for the datagram transmission from the terminal within the network to the terminal within the other network.

DETD Now, in this case, the protocol at the terminal is as follows. Namely, when the terminal judges that the datagram is destined to the external sub-network, the terminal transmits the datagram to the CLSF-O. Here, the **ATM** connection is assumed to be already set up between the terminal and the CLSF-O. Each terminal has the address space data (such as address masks) for the sub-network to which it belongs, so that it is possible for each terminal to judge whether the destination terminal is

the terminal within its own network or the terminal of the external sub-network.

DETD (1) In this scheme, the CLSF-O and the CLSF-I are located at the same access point, and the star-shaped **ATM** connections are set up from between the CLSF and the terminals. The terminal transmits the cell to the CLSF whenever the datagram transmission is to be carried out. The datagram delivery is entirely carried out by the CLSF. Namely, even the communication between the terminals within the same sub-network is realized via the CLSF.

DETD In this case, the star-shaped **ATM** connections (bidirectional communication channels) are formed from the ARS 63G in the network 631 to the ARSs 63D, 63E, and 63F in the networks 632 to 634, respectively, as shown in FIG. 28. For example, in order to utilize the **ATM** connection set up between the CLSF-O 63M and the CLSF-I 63J so as to transmit the datagram from the terminal 63A to the terminal 63B, there is a need for the CLSF-O 63M to obtain the VCI/VPI data of this **ATM** connection. In order to obtain this VCI/VPI, the CLSF-O 63M transmits the AR request cell having the address data of the terminal 47B to the ARS 63D of its own network 632 which is the address data written in the received datagram. The ARS 63D which received this AR request cell then analyzes the address of the destination terminal written in the received cell, and when It Is impossible to carry out the **address resolution** from the data possessed by it, the ARS 63D relays the AR request cell to the ARS 63G in the network 631 through the already set up **ATM** connection 651.

DETD Here, the **address resolution** at the ARS 63G is carried out as follows. Namely, the ARS 63G has the address data (address space data) of the terminals contained in its own network 631 and the address space data for the sub-networks 632 to 634. Then, the ARS 63G analyzes the transmission target network by comparing the address written in the received AR request cell with the address space data for each sub-network.

DETD In this manner, the ARS 63G possesses the addresses and the address space data of the terminals belonging to the network 631 and the sub-networks 632, 633, and 634, so as to carry out the **address resolution**. Here, it is not necessary for the ARS 63G to possess the address data up to the terminal level for the sub-network other than its own sub-network, and it suffices to possess the address data only up to the network address level.

DETD The address data (**ATM** layer address data) received by the ARS 63D from the ARS 63G is the data indicating the identifier (normally VCI/VPI, but may contain the identification data for the upper layer) of the **ATM** connection to the CLSF-I in the target sub-network from the IWU 636. For example, at a time of the datagram transmission from the terminal 63A to the terminal 63B, the identifier of the **ATM** connection 645 for making an access to the CLSF-I 63J is notified as the AR response, whereas at a time of the datagram transmission from the terminal 63A to the terminal 63C, the identifier of the **ATM** connection 642 for making an access to the CLSF-I 63L is notified as the AR response.

DETD Here, the ARS 63D notifies the VCI/VPI data for correctly relaying the **ATM** connection at the IWU 636 to the CLSF-O 63M, according to the VCI/VPI data received from the ARS 463G. The VCI/VPI data notified to the CLSF-O 63M is then rewritten into the other VCI/VPI at the IWU 636.

DETD In this case, the star-shaped **ATM** connections as shown in FIG. 28 described above is formed from the ARS 63G in the network 631 to the ARSs 632 to 634 in the networks 632 to 634, respectively, or the meshed **ATM** connections as shown in FIG. 29 is formed by the ARSs 63D to

63G. Each ARS obtains the address space data and the **ATM** connection data (VCI/VPI) for the external sub-networks viewed from its own sub-network using the **ATM** connections defined as shown in FIG. 28 or FIG. 29. Here, FIG. 28 is in a form in which the ARS 63G functions as a master ARS, while FIG. 29 is in a distributed form in which each ARS operates independently. In a case the number of hierarchical levels in the network is at most three, a case of FIG. 28 to make the backbone network as the master is more appropriate.

DETD Here, the **address resolution** at the ARS 63D is carried out as follows. Namely, the ARS 63D has the address data (address space data) of the terminals contained in its own network 632 and the address space data for the sub-networks 631, 633, and 634. Then, the ARS 63D analyzes the transmission target network by comparing the address written in the received AR request cell with the address space data for each sub-network.

DETD In this manner, the ARS 63D possesses the addresses and the address space data of the terminals belonging to the network 632 and the sub-networks 631, 633, and 634, so as to carry out the **address resolution**. Here, it is not necessary for the ARS 63D to possess the address data up to the terminal level for the sub-network other than its own sub-network, and it suffices to possess the address data only up to the network address level.

DETD The address data (**ATM** layer) received by the ARS 63D from the other ARS is the data indicating the identifier (normally VCI/VPI, but may contain the identification data for the upper layer) of the **ATM** connection to the CLSF-I in the target sub-network from the IWU 636. For example, at a time of the datagram transmission from the terminal 63A to the terminal 63B, the identifier of the **ATM** connection 645 for making an access to the CLSF-I 63J is notified as the AR response, whereas at a time of the datagram transmission from the terminal 63A to the terminal 63C, the identifier of the **ATM** connection 642 for making an access to the CLSF-I 63L is notified as the AR response. Here, the ARS 63D notifies the VCI/VPI data for correctly relaying the **ATM** connection at the IWU 636 to the CLSF-O 63M, according to the VCI/VPI data received from the other ARS. The VCI/VPI data notified to the CLSF-O 63M is then rewritten into the other VCI/VPI at the IWU 636.

DETD Among ARSs, not only the address space data exchange protocol for each sub-network, but also the routing protocol concerning the datagram transmission (connection-less communication) among the sub-networks is also operated. More specifically, this routing protocol carries out the management of the **ATM** connection setting as shown in FIG. 30 described above. Here, the individual **ATM** connection is separated at the IWU (i.e., closed within the sub-network), and the **ATM** connection routing control and the **ATM** connection management (such as VCI/VPI management) are made by the other **ATM** connection **server** process and the routing **server** process, and the ARS exchanges the control messages with these **servers** as well as the IWU to carry out the management of the **ATM** connections necessary for the connection-less communication.

DETD Thus, it suffices for each CLSF to possess only the address data of the terminals of the network to which that CLSF itself belongs. When the address of the of the received datagram is present in its own network, the appropriate **ATM** connection is selected and the relaying of the datagram is carried out.

DETD An exemplary protocol processing in a case of transmitting the datagram from the terminal 63A to the terminal 63B is shown in FIG. 32. Namely, the **ATM** connection is terminated at the CLSF-O 63M and the

CLSF-I 63J, i.e., the protocol of the OSI layer 3 is terminated at the CLSF-O 63M and the CLSF-I 63J. In this manner, at a time of the datagram transmission to the terminal other than those of its own sub-network, the end-to-end datagram delivery can be realized with only two **ATM** connection termination.

DETD In this case, the **address resolution** is carried out as follows.

DETD In transmitting the datagram from the terminal 63A to the terminal 63B, when the terminal 63A recognizes that the terminal 63B belongs to the external sub-network, the terminal 63A transmits the datagram to the CLSF-O 63M. The CLSF-O 63M then analyzes the address data of the received datagram, and transmits the AR request cell having the address data of the terminal 63B to the ARS 63D when the CLSF-O 63M does not have the **ATM** layer address data for transmitting the datagram to the terminal 63B (or to the CLSF-I 63J).

DETD When the ARS 63D possesses the data enabling the **address resolution**, the AR request containing the VCI/VPI for transmitting the cell from the CLSF-O 63M to the CLSF-I 63J is directly transmitted. On the other hand, when the **address resolution** cannot be made at the ARS 63D, the appropriate ARS is accessed to carry out the **address resolution**. When the **address resolution** is completed, the resulting AR response is transmitted to the CLSF-O 63M.

DETD The terminal 63A transmits the cell having the datagram information to the CLSF-O 63M through the **ATM** connection 641. The CLSF-O 63M then analyzes the address data of the datagram, cell assembles the datagram, and transmits the cell to the CLSF-I 63J by using the **ATM** connection 645. The IWUs 636 and 637 carries out the relaying of the **ATM** connection by rewriting the VCI/VPI data of the received cell.

DETD At the CLSF-I 63J which is the terminal point of the **ATM** connection 645, the network layer processing is carried out. The CLSF-I 63J carries out the analysis of the network address, and the datagram is relayed to the **ATM** connection 646 and transmitted to the terminal 63B.

DETD In this manner, there are only three **ATM** connections from the terminal 63A to the CLSF-O 63M, from CLSF-O 63M to the CLSF-I 63J, and from the CLSF-I 63J to the terminal 63B, so that they are terminated only twice.

DETD In this case, the manner of realizing the **ATM** connections set up among the ARSs is equivalent to that described above as 3. General **ATM** network: Scheme II, so that it will not be repeated here.

DETD With reference to FIG. 30 described above and FIG. 33, four available schemes for the setting of the **ATM** connections required for transmitting the datagram from the terminal 63A to the terminal 63C, the public network 635, and the terminal 63B will be described.

DETD In this case, three **ATM** connections are required. One is formed by the connection 691 between the terminal 63A and the CLSF-O 63M, another is formed by the connections 692 and 693 between the CLSF-O 63M and the CLSF-I 63L, and still another is the connection 694 between the CLSF-I 63L and the terminal 63C. The terminal 63A transmits to the IWU 636 the cell with the VPI-F having VPI.sub.63M which is the access address of the CLSF-O 63M, and the VCI-F1 having VPI.sub.63A which is the access address of the terminal 63A. Then, the CLSF-O 63M transmits to the IWU 636 the cell with the VPI-F having VPI.sub.636-2 which is the access address of the IWU 636 for the network 632, the VCI-F1 having the VPI.sub.63M which is the access address of the CLSF-O 63M, and the VCI-F2 having a value set at a time of setting the connection 692. The IWU 636 analyzes the VCI of the received cell, as well as the

corresponding VPI-F and the VCI-F2. Then, to the VCI-F1, VPI.sub.636-1 which is the access address of the IWU 636 for the network 631 is written. Here, the VCI-F2 is a value which is determined at a time of setting the connection 693, which can be written by copying the value of the VCI-F1 of the cell received by the IWU 636, i.e., the VPI.sub.63M which is the access address of the CLSF-O 63M.

DETD The datagram arrived at the CLSF-I 63L is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63L analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63C. Then, the CLSF-I 63L generates the cell with the VPI-F having VPI.sub.63C which is the access address of the terminal 63C, the VCI-F1 having the VPI.sub.63L which is the access address of the CLSF-I 63L, and the VCI-F2 having an identification number assigned to the connection 694, and transmits the datagram to the terminal 63C. Here, the terminal 63C can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63C.

DETD In this case, two **ATM** connections is required. One is formed by the connection 691 between the terminal 63A and the CLSF-O 63M, while the other is formed by the connections 692, 695, and 696 between the terminal CLSF-O 63M and the public network 635. The terminal 63A transmits the cell with the VPI-F having VPI.sub.63M which is the access address of the CLSF-O 63M. Then, the CLSF-O 63M transmits to the IWU 636 the cell with the VPI-F having VPI.sub.836-2 which is the access address of the IWU 636 for the network 632, the VCI-F1 having the VPI.sub.63M which is the access address of the CLSF-O 63M, and the VCI-F2 having a value set at a time of setting the connection 692. The IWU 638 analyzes the VCI of the received cell, as well as the corresponding VPI-F and the VCI-F2. Then, to the VCI-F1, VPI.sub.636-1 which is the access address of the IWU 636 for the network 631 is written. Here, the VCI-F2 is a value which is determined at a time of setting the connection 695, which can be written by copying the value of the VCI-F1 of the cell received by the IWU 636, i.e., the VPI.sub.63M which is the access address of the CLSF-O 63M. The IWU 639 writes the VCI/VPI assigned to the **ATM** connection 696 defined by the public network 635 according to the VCI data of the received cell, and transmits the cell to the public network 635.

DETD In this case, three **ATM** connections are required. One is formed by the connection 691 between the terminal 63A and the CLSF-O 63M, another is formed by the connections 692, 697, and 698 between the CLSF-O 63M and the CLSF-I 63J, and still another is formed by the connection 699 between the CLSF-I 63J and the terminal 63B. The terminal 63A transmits the cell with the VPI-F having VPI.sub.63M which is the access address of the CLSF-O 63M. Then, the CLSF-O 63M transmits to the IWU 636 the cell with the VPI-F having VPI.sub.636-2 which is the access address of the IWU 636 for the network 632, the VCI-F1 having the VPI.sub.63M which is the access address of the CLSF-O 63M, and the VCI-F2 having a value set at a time of setting the connection 692. The IWU 636 analyzes the VCI of the received cell, as well as the corresponding VPI-F and the VCI-F2. Then, to the VCI-F1, VPI.sub.636-1 which is the access address of the IWU 636 for the network 631 is written. Here, the VCI-F2 is a value which is determined at a time of setting the connection 697, which can be written by copying the value of

the VCI-F1 of the cell received by the IWU 636, i.e., the VPI.sub.63M which is access address of the CLSF-O

DETD The datagram arrived at the CLSF-I 63J is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63J analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63B. Then, the CLSF-I 63J generates the cell with the VPI-F having VPI.sub.63B which is the access address of the terminal.sub.63B, the VCI-F1 having the VPI.sub.63J which is the access address of the CLSF-I 63J, and the VCI-F2 having an identification number assigned to the connection 699, and transmits the datagram to the terminal 63B. Here, the terminal 63B can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63A.

DETD In this scheme, each CLSF-O carries out the re-assembling of the datagram, but the **address resolution** is carried out by each terminal. The address data of the target network obtained by the **address resolution** is written in the VCI-F1 of the cell transmitted from the terminal to the CLSF-O. Here, the cell transmission (datagram transmission) from the CLSF-O cannot be carried out in the pipeline-like manner, but there is no need for the CLSF-O to carry out the **address resolution** of the network to which the destination terminal belongs according to the address data in the received datagram.

DETD In this scheme, each IWU, CLSF-O and CLSF-I has obtained the VPI address, and all the connections identified by the obtained VPIs are **ATM** connections to be used for the cell transmission related to the datagram transmission (connection-less communication). Namely, each of the CLSF **server** and the IWU requires the **ATM** connection (not connection-less one) in order for itself to carry out the communication with the other terminal/**server**. In other words, there is a need for the CLSF to obtain at least two access addresses (VPIs) at a time of the boot.

DETD By the scheme as in the above, in the procedure for the **address resolution** which precedes the datagram transmission, the terminal can transmits the datagram (one or more cells) as long as the identification number of the sub-network to which the destination terminal belongs. This datagram transmission will now be described in detail.

DETD The datagram arrived at the CLSF-I 63L is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63L analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63C. Then, the CLSF-I 63L generates the cell with the VPI-F having VPI.sub.63C which is the access address of the terminal 63C, and transmits the datagram to the terminal 63C. Here, the terminal 63C can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63C.

DETD The IWU 639 writes the VCI/VPI assigned to the **ATM** connection 696 defined by the public network 635 according to the VCI data of the received cell, and transmits the cell to the public network 635.

DETD The datagram arrived at the CLSF-I 63J is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63J analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63B. Then, the CLSF-I 63J generates the cell with the VPI-F having VPI.sub.63B which is the access address of the terminal 63D, and transmits the datagram to the terminal 63D. Here, the terminal 63B can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63B.

DETD In this scheme, each CLSF-0 carries out the re-assembling of the datagram, but the **address resolution** is carried out by each terminal, so that there is no need for the CLSF-0 to carry out the **address resolution** of the network to which the

destination terminal belongs according to the address data within the received datagram. The address data of the target network obtained by the **address resolution** is written in the VCI-F1 of the cell transmitted from the terminal to the CLSF-0.

DETD The datagram arrived at the CLSF-I 63L is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63L analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63C. Then, the CLSF-I 63L generates the cell with the VPI-F having VPI.sub.63C which is the access address of the terminal 63C, and transmits the datagram to the terminal 63C. Here, the terminal 63C can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63C.

DETD The IWU 639 writes the VCI/VPI assigned to the **ATM** connection 696 defined by the public network 635 according to the VCI data of the received cell, and transmits the cell to the public network 635.

DETD The datagram arrived at the CLSF-I 63J is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63J analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63B. Then, the CLSF-I 63J generates the cell with the VPI-F having VPI.sub.63B which is the access address of the terminal 63D, and transmits the datagram to the terminal 63D. Here, the terminal 63B can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63B.

DETD In this scheme, each CLSF-0 carries out the reassembling of the datagram, but the **address resolution** is carried out by each terminal, so that there is no need for the CLSF-0 to carry out the **address resolution** of the network to which the destination terminal belongs according to the address data within the received datagram. The address data of the target network obtained by the **address resolution** is written in the VCI-F1 of the cell transmitted from the terminal to the CLSF-0.

DETD Step 4: The end of the datagram transmission can be recognized by the CLSF-0 according to the identification codes above the **ATM** layer such as those of the payload type coding in the AAL 5 for example.

In a case there is no other datagram transmission with respect to the analyzed target sub-network, the received cell is relayed to the target sub-network. Here, the received cell is transmitted in the pipeline-like manner, i.e., without being re-assembled once at the CLSF-0.

DETD The datagram arrived at the CLSF-I 63L is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63L analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63C. Then, the CLSF-I 63L generates the cell with the VPI-F having VPI.sub.63C which is the access address of the terminal 63C, and transmits the datagram to the terminal 63C. Here, the terminal 63C can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63C.

DETD The IWU 639 writes the VCI/VPI assigned to the **ATM** connection 696 defined by the public network 635 according to the VCI data of the received cell, and transmits the cell to the public network 635.

DETD The datagram arrived at the CLSF-I 63J is cell re-assembled once, and the **ATM** connection is terminated. The CLSF-I 63J analyzes the upper layer address data and recognizes that the destination of the datagram as the terminal 63B. Then, the CLSF-I 63J generates the cell with the VPI-F having VPI.sub.63B which is the access address of the terminal 63D, and transmits the datagram to the terminal 63D. Here, the terminal 63B can uniquely identify the datagram to which the cell belongs from the VCI-F1 and the VCI-F2. Namely, the datagram can be re-assembled at the terminal 63B.

DETD FIG. 34 shows a system configuration of the network with the falt topology, in which a plurality of sub-networks 701 to 706 with the

inter-networking provided by the IWUs 70D, 70E, 70F, 70G, 70H, and 70J. In addition, the public networks 707 and 708 are connected with the networks 703 and 704 through the IWUs 70K and 70M, respectively. Here, each IWU can realize the relaying of the **ATM** cells without terminating the **ATM** connection, by having a function to convert the VCI/VPI of the received cell into VCI/VPI assigned to the corresponding **ATM** connection in the neighboring network.

DETD Also, in this case, the manner of realizing the **address resolution** is basically equivalent to that in the hierarchical network described above, so that the description concerning the manner of constructing the **ATM** connections related to the **address resolution** will not be repeated here. Namely, there are two schemes including a scheme in which all the **address resolution servers** are equal and analyze the address data of the network independently, and a scheme in which the address data are managed and analyzed by the logical hierarchical structure among the **address resolution servers**. As for the **ATM** connections to be set up among the **address resolution servers**, they can have any desired structure ranging from the full meshed structure to the minimally spanning tree structure.

DETD 1. General **ATM** Network: Scheme I

DETD In this case, the **ATM** connections are provided as follows. Namely, in order to transmit the datagram from the terminal connected to each sub-network to the terminal connected to an optional sub-network, the **ATM** connections are set up from each IWU to the CLSFs provided within all the sub-networks. That is, the single direction **ATM** connections from the IWU to the CLSFs are set up in the fully meshed manner. Here, the IWU (relaying IWU) provided on the route of the **ATM** connection carries out the rewriting of the **ATM** header data or at least the VCI/VPI conversion, and the cell relaying is executed as the work at the **ATM** layer. In other words, the **ATM** connection is not terminated in principle at the IWU. Also, it is also possible for the CLSF to be provided at a position of the IWU if desired.

DETD Here, when the datagram is transmitted to the network defined by the public networks 707 and 708, the received cell to which the datagram belongs is transmitted to the **server** for terminating the datagram connection of the public network once. This **server** can also be provided on the IWU if desired. The **server** which terminated the datagram transmitted from the public network relays the datagram by the same procedure as the datagram transmission from the terminal within the defined network.

DETD The exemplary **ATM** connection configuration at a time of transmitting the datagram from the public network 707 to the terminal 70A is shown in FIG. 35. In this exemplary case, the datagram transmitted from the public network 707 is terminated at the CLSF-P 811 once, and then transmitted to the terminal 70A via the CLSF 7011. Therefore, there are three **ATM** connections 812, 813, and 814.

DETD (1) The terminal makes the AR request. This can be done either always or only in a case the **address resolution** cannot be made by the terminal itself such as a case in which a suitable entry is present in the AR table.

DETD (2) The terminal obtains the VCI/VPI data which is the identifier of the **ATM** connection provided from the ARS in order to make an access to the destination terminal.

DETD Here, at a time of the datagram transmission, there is no need for the terminal to carry out the procedure for setting up a particular connection defined in the **ATM** network.

DETD Thus, it suffices for each CLSF to possess only the address data of the terminals of the network to which that CLSF itself belongs. When the

address of the of the received datagram is present in its own network, the appropriate **ATM** connection is selected and the relaying of the datagram is carried out.

DETD An exemplary protocol processing in a case of transmitting the datagram from the public network 707 to the terminal 70A through the **ATM** connections of FIG. 35 described above is shown in FIG. 36. Similarly, an exemplary protocol processing in a case of transmitting the datagram from the terminal 70A to the terminal 70B through the **ATM** connections of FIG. 37 is shown in FIG. 38 for the datagram relayed through paths 771 to 776 shown in FIG. 39. In this case, the **ATM** connection is terminated at the CLSF 7061 once, i.e., the protocol of the OSI layer 3 is terminated at the CLSF 7061. The OSI layer 3 protocol processing is carried out at the CLSF 7061, and the data unit is transmitted to the terminal 70B using the **ATM** connection. In this manner, at a time of the datagram transmission to the terminal other than those of its own sub-network, the end-to-end datagram delivery can be realized with only one **ATM** connection termination.

DETD Similarly, an exemplary protocol processing in a case of transmitting the datagram from the terminal 70A to the public network 708 through the **ATM** connections of FIG. 40 is shown in FIG. 41 for the datagram relayed through paths 781 to 783 shown in FIG. 42.

DETD In transmitting the datagram from the terminal 70A to the terminal 70B, the required **ATM** connection configuration is as shown in FIG. 37. Here, at a time of the datagram transmission, the terminal 70A carries out the **address resolution** of the terminal 70B by analyzing the access address data of the sub-network to which the terminal 70B belongs. Namely, the terminal 70A transmits the AR request message containing the address data of the terminal 70B to the ARS. The ARS which received this AR request then carries out the **address resolution** and returns to the terminal 70A the AR response indicating the VCI/VPI data for transmitting the cell to the terminal 70B.

DETD The terminal 70A which obtained the **ATM** layer address (VCI/VPI) data for transmitting the cell to the terminal 70B then outputs the cell attached with the VCI/VPI to the network. Then, after the VCI/VPI conversion at the IWU 70D, the cell is transmitted to the IWU 70G. Similarly, the cell is transmitted to the CLSF 7061 via the IWUs 70H and 70J. The CLSF 7061 which received this cell then analyzes the layer 3 address data of the datagram and transmits the cell to the terminal 70B. Here, the cell transmission from the CLSF 7061 to the terminal 70B may be made after all the cells belonging to the datagram are received by the CLSF 7061, or by the pipeline-like cell relaying after the analysis of the layer 3 address data of the datagram.

DETD In transmitting the datagram from the terminal 70A to the public network 708, the required **ATM** connection configuration is as shown in FIG. 40. Here, at a time of the datagram transmission, the terminal 70A carries out the **address resolution** of the target terminal by analyzing the access address data of the sub-network to which the destination terminal belongs. Namely, the terminal 70A transmits the AR request message containing the address data of the destination terminal to the ARS. The ARS which received this AR request then carries out the **address resolution** and returns to the terminal 70A the AR response indicating the VCI/VPI data for transmitting the cell to the destination terminal.

DETD The terminal 70A which obtained the **ATM** layer address (VCI/VPI) data for transmitting the cell to the terminal 70B then outputs the cell attached with the VCI/VPI to the network. Then, after the VCI/VPI conversion at the IWU 70D, the cell is transmitted to the IWU 70E. Similarly, the cell is transmitted to the public network 708 via the IWU 70M.

DETD In transmitting the datagram from the public network 707 to the terminal 70A, the required **ATM** connection configuration is as shown in FIG. 35. Here, the transmission source terminal Is present within the public network 707, and the cell related to the connection-less communication from the public network 707 is transmitted to the CLSF-P 811 via the IWU 70K. The VCI/VPI conversion table provided at the IWU 70K is set such that the cell is transmitted to the CLSF-P 811 whenever the cell having the VCI/VPI assigned to the cell used by the connection-less communication in the public network 707 has arrived.

DETD The CLSF-P 811 terminates the **ATM** connection once, and analyzes the layer 3 address data of the datagram. In a case the address data to be analyzed is not present in the table within the CLSF-P 811, the CLSF-P 811 transmits the AR request to the ARS. The CLSF-P 811 which obtained the **ATM** layer address (VCI/VPI) data for transmitting the cell to the terminal 70A then outputs the cell attached with the VCI/VPI to the network. After the VCI/VPI conversion at the IWU 70G, the cell is transmitted to the IWU 70D, and then to the CLSF 7011. The CLSF 7011 which received the cell then analyzes the layer 3 address data of the datagram, and transmits the cell to the terminal 70A. Here, the cell transmission from the CLSF 7011 to the terminal 70A and the cell transmission from the CLSF-P 811 to the IWU 70G may be made after all the cells belonging to the datagram are received by the CLSF 7061 or the CLSF-P 811, or by the pipeline-like cell relaying after the analysis of the layer 3 address data of the datagram.

DETD 2. General **ATM** Network: Scheme II

DETD In this case, the **ATM** connections are provided as follows. Namely, in order to transmit the datagram from the terminal connected to each sub-network to the terminal connected to an optional sub-network, the **ATM** connections are set up from each CLSF to the CLSFs provided within all the sub-networks. That is, the **ATM** connections among the CLSFs are set up in the fully meshed manner. Here, the IWU (relaying IWU) provided on the route of the **ATM** connection carries out the rewriting of the **ATM** header data or at least the VCI/VPI conversion, and the cell relaying is executed as the work at the **ATM** layer. In other words, the **ATM** connection is not terminated in principle at the IWU. Also, it is also possible for the CLSF to be provided at a position of the IWU if desired.

DETD Here, when the datagram is transmitted to the network defined by the public networks 707 and 708, the received cell to which the datagram belongs is transmitted to the **server** for terminating the datagram connection of the public network once. This **server** can also be provided on the IWU if desired. The **server** which terminated the datagram transmitted from the public network relays the datagram by the same procedure as the datagram transmission from the terminal within the defined network.

DETD The exemplary **ATM** connection configuration at a time of transmitting the datagram from the public network 707 to the terminal 70A is shown in FIG. 43. In this exemplary case, the datagram transmitted from the public network 707 is terminated at the CLSF-P 811 once, and then transmitted to the terminal 70A via the CLSFs 7031 and 7011. Therefore, there are four **ATM** connections 831, 832, 833, and 834.

DETD Now, in this case, the protocol at the terminal is as follows. Namely, when the terminal Judges that the datagram is destined to the external sub-network, the terminal transmits the datagram to the CLSF. This CLSF is usually present in the same sub-network as the terminal, but the CLSF

may be provided at the other sub-network such as that of the neighboring node if desired. Here, the **ATM** connection is assumed to be already set up between the terminal and the CLSF. Each terminal has the address space data (such as address masks) for the sub-network to which it belongs, so that it is possible for each terminal to judge whether the destination terminal is the terminal within its own network or the terminal of the external sub-network.

DETD An exemplary protocol processing in a case of transmitting the datagram from the public network 707 to the terminal 70A through the **ATM** connections of FIG. 43 described above is shown in FIG. 44.

DETD (1) In this scheme, the star-shaped **ATM** connections are set up from between the CLSF and the terminals. The terminal transmits the cell to the CLSF whenever the datagram transmission is to be carried out. The datagram delivery is entirely carried out by the CLSF. Namely, even the communication between the terminals within the same sub-network is realized via the CLSF.

DETD Thus, it suffices for each CLSF to possess only the address data of the terminals of the network to which that CLSF itself belongs. When the address of the of the received datagram is present in its own network, the appropriate **ATM** connection is selected and the relaying of the datagram is carried out.

DETD An exemplary **ATM** connection configuration in a case of transmitting the datagram from the terminal 70A to the terminal 70B is shown in FIG. 45 for the datagram relayed through the paths 791 to 797 shown in FIG. 46. Namely, the **ATM** connection is terminated at the CLSFs 7061 and 7011. The OSI layer 3 protocol processing is carried out at the CLSF 7011, and the data unit is transmitted to the IWU 70D using the **ATM** connection. Also, the OSI layer 3 protocol processing is carried out at the CLSF 7061, and the data unit is transmitted to the terminal 70B using the **ATM** connection. In this manner, at a time of the datagram transmission to the terminal other than those of its own sub-network, the end-to-end datagram delivery can be realized with only two **ATM** connection terminations.

DETD Similarly, an exemplary **ATM** connection configuration in a case of transmitting the datagram from the terminal 70A to the public network 708 is shown in FIG. 47 for the datagram relayed through the paths 801 to 804 shown in FIG. 48.

DETD In transmitting the datagram from the terminal 70A to the terminal 70B, the required **ATM** connection configuration is as shown in FIG. 45. Here, at a time of the datagram transmission, the terminal 70A transmits the datagram to the CLSF 7011 when it is analyzed that the terminal 70B is the terminal belonging to the external sub-network. The CLSF 7011 then analyzes the address data of the received datagram, and transmits the AR request cell having the address data of the terminal 70B to the ARS when it does not possess the **ATM** layer address data for transmitting the datagram to the terminal 70B (CLSF 7061). The ARS which received this AR request then carries out the **address resolution** and returns to the CLSF 7011 the AR response indicating the VCI/VPI data for transmitting the cell to the CLSF 7061 (terminal 70B).

DETD The CLSF 7011 which obtained the **ATM** layer address (VCI/VPI) data for transmitting the cell to the terminal 70B then outputs the cell attached with the VCI/VPI to the network. Then, after the VCI/VPI conversion at the IWU 70D, the cell is transmitted to the IWU 70G. Similarly, the cell is transmitted to the CLSF 7061 via the IWUs 70H and 70J. The CLSF 7061 which received this cell then analyzes the layer 3 address data of the datagram and transmits the cell to the terminal 70B.

Here, the cell transmission from the CLSF 7061 to the terminal 70B may be made after all the cells belonging to the datagram are received by the CLSF 7061, or by the pipeline-like cell relaying after the analysis of the layer 3 address data of the datagram.

DETD In transmitting the datagram from the terminal 70A to the public network 708, the required **ATM** connection configuration is as shown in FIG. 47. Here, at a time of the datagram transmission, the terminal 70A carries out the **address resolution** of the target terminal by analyzing the access address data of the sub-network to which the destination terminal belongs. Namely, the terminal 70A transmits the AR request message containing the address data of the destination terminal to the ARS when the terminal 70A cannot carry out the resolution of the address data of the destination terminal. The ARS which received this AR request then carries out the **address resolution** and returns to the terminal 70A the access address data of the CLSF 7011 with the AR response indicating the VCI/VPI data for transmitting the cell to the destination terminal. Then, when it is analyzed that the destination terminal is the terminal belonging to the external sub-network, the terminal 70A attaches the VCI/VPI data either received or obtained from the analysis, and transmits the cell to the CLSF 7011.

DETD The CLSF 7011 then analyzes the address data of the received datagram, and transmits the AR request cell having the address data of the destination terminal to the ARS when it does not possess the **ATM** layer address data for transmitting the datagram to the destination terminal. The ARS which received this AR request then carries out the **address resolution** and returns to the CLSF 7011 the AR response indicating the VCI/VPI data for transmitting the cell to the IWU 70M.

DETD The CLSF 7011 which obtained the **ATM** layer address (VCI/VPI) data for transmitting the cell to the terminal 70B then outputs the cell attached with the VCI/VPI to the network. Then, after the VCI/VPI conversion at the IWU 70D, the cell is transmitted to the IWU 70E. Similarly, the cell is transmitted to the public network 708 via the IWU 70M.

DETD In transmitting the datagram from the public network 707 to the terminal 70A, the required **ATM** connection configuration is as shown in FIG. 43. Here, the transmission source terminal is present within the public network 707, and the cell related to the connection-less communication from the public network 707 is transmitted to the CLSF-P 811 via the IWU 70K. The VCI/VPI conversion table provided at the IWU 70K is set such that the cell is transmitted to the CLSF-P 811 whenever the cell having the VCI/VPI assigned to the cell used by the connection-less communication in the public network 707 has arrived.

DETD The CLSF-P 811 terminates the **ATM** connection once, and analyzes the layer 3 address data of the datagram. In a case the address data to be analyzed is not present in the table within the CLSF-P 811, the CLSF-P 811 transmits the AR request to the ARS. The CLSF-P 811 which obtained the **ATM** layer address (VCI/VPI) data for transmitting the cell to the CLSF 7031 then outputs the cell attached with the VCI/VPI to the network. The CLSF 7013 then analyzes the address data of the receive datagram

DETD The CLSF 7031 then analyzes the address data of the received datagram, and transmits the AR request cell having the address data of the terminal 70A to the ARS when it does not possess the **ATM** layer address data for transmitting the datagram to the terminal 70A (CLSF 7011). The ARS which received this AR request then carries out the **address resolution** and returns to the CLSF 7031 the AR response indicating the VCI/VPI data for transmitting the cell to the

CLSF 7011 (terminal 70A).

DETD The CLSF 7011 which obtained the **ATM** layer address (VCI/VPI) data for transmitting the cell to the terminal 70A then outputs the cell attached with the VCI/VPI to the network.

DETD First, the coding of the VCI/VPI field of the cell from the transmission source terminal to the CLSF can be done as follows. Namely, in this case, the VPI-F is an access address of the CLSF, while the VCI-F2 is defined as the access address of the transmission source terminal. As for the VCI-F1, there are two cases of carrying out the **address resolution** of the sub-network to which the destination terminal belongs either at the transmission source terminal or at the CLSF.

DETD (a) In a case of carrying out the **address resolution** at the transmission source terminal, the identification number Net.sub.destination of the destination sub-network obtained by the transmission source terminal is written into the VCI-F1.

DETD (b) In a case of carrying out the **address resolution** at the CLSF, the VCI-F1 can be set as an arbitrary value.

DETD Next, the coding of the VCI/VPI field of the cell from the CLSF to the IWU can be done as follows. Namely, in this case, the VPI-F is an access address of the IWU, and the VCI-F1 is set to be the identification number Net.sub.destination of the destination network, while the VCI-F2 is set to be the identification number Net.sub.source of the network of the transmission source terminal. Here, again, for the setting of the VCI-F1, there are two cases of carrying out the **address resolution** of the sub-network to which the destination terminal belongs either at the transmission source terminal or at the CLSF.

DETD (a) In a case of carrying out the **address resolution** at the transmission source terminal, the identification number Net.sub.destination of the destination sub-network obtained by the transmission source terminal is copied into the VCI-F1.

DETD (b) In a case of carrying out the **address resolution** at the CLSF, a value obtained by the **address resolution** is written into the VCI-F1.

DETD First, with references to FIGS. 45 and 46, the datagram transmission from the terminal 70A to the terminal 70B will be described. In this case, three **ATM** connections are required, one formed by the connection 791 from the terminal 70A to the CLSF 7011, another formed by the connections 792 to 796 from the CLSF 7011 to the CLSF 7961, and still another formed by the connection 797 from the CLSF 7061 to the terminal 70B.

DETD The terminal 70A transmits the cell with the VPI-F having VPI.sub.7011, while the VCI-F2 has VPI.sub.70A which is the access address of the terminal 70A itself. Also, when the terminal 70A carries out the **address resolution** of the address data (Net.sub.706) of the sub-network to which the destination terminal belongs by itself, this value Net.sub.706 is written into the VCI-F1. On the other hand, when the CLSF 7011 carries out the **address resolution** , the VCI-F1 can be set to an arbitrary value.

DETD The IWU 70J recognizes that the cell has reached the target network according to the VCI-F1 data, and transmits the cell to the CLSF 7061. The datagram arrived to the CLSF 7061 is cell re-assembled once, and the **ATM** connection is terminated. The CLSF 7061 analyzes the address data of the upper layer and recognizes that the destination of the datagram as the terminal 70B. Then, the CLSF 7061 generates the cell and transmits the datagram to the terminal 70B. Here, the cell transmission to the terminal 70B can be done in the pipeline-like manner since the cell reception at the CLSf 7061 when there are sufficient amount of the connection-less communication channels to the terminal 70B

DETD Next, with reference to FIG. 47, the datagram transmission from the

terminal 70A to the public network 708 is described. The terminal 70A transmits the cell with VPI-F having VPI.sub.7011, while the VCI-F2 has VPI.sub.70A which is the access address of the terminal 70A itself. Also, when the terminal 70A carries out the **address resolution** of the address data (Net.sub.708) of the sub-network to which the destination terminal belongs by itself, this value Net.sub.708 is written into the VCI-F1. On the other hand, when the CLSF 7011 carries out the **address resolution**, the VCI-F1 can be set to an arbitrary value.

DETD The IWU 70M writes the VCI/VPI assigned to the **ATM** connection defined by the public network 708 from the VCI data of the received cell, and transmits the cell to the public network.

DETD In this case, four **ATM** connections 881 to 884 as shown in FIG. 52 are required, including an **ATM** connection 881 from the terminal 87A of the network 881 to a CLSF 871 of the network 862, an **ATM** connection 882 from the CLSF 871 to a CLSF 872 of a sub-network in the network 863 connected with the network 862, an **ATM** connection 883 from the CLSF 872 to a CLSF 873 of a sub-network in the network 863 connected with the terminal 87B, and an **ATM** connection 884 from the CLSF 873 to the terminal 87B.

DETD The terminal 87A carries out the **address resolution** of the network layer address of the terminal 87B to recognize that the terminal 87B belongs to the network 851, while also obtains the VCI/VPI data for transmitting the cell to the CLSF 871 in the manner similar to that described above. Then, the datagram is transmitted from this terminal 87A to the CLSF 871 through the **ATM** connection 881.

DETD The datagram and the **ATM** connection are terminated once by the CLSF 871 at which the layer 3 protocol processing for analyzing the network layer address of the datagram is carried out. As a result, it is recognized that the terminal 87B is present in the network 863, while also obtains the VCI/VPI data for transmitting the cell to the CLSF 872. Then, the datagram is transmitted from this CLSF 871 to the CLSF 872 through the **ATM** connection 882.

DETD The datagram and the **ATM** connection are terminated again by the CLSF 872 at which the layer 3 protocol processing for analyzing the network layer address of the datagram is carried out, while the VCI/VPI data for transmitting the cell to the CLSF 873 is also obtained. Then, the datagram is transmitted from this CLSF 872 to the CLSF 873 through the **ATM** connection 883.

DETD The CLSF 873 which received the datagram then analyzes the network layer address of the datagram to analyze the access address of the terminal 87B. Then, the cell with the appropriate VCI/VPI attached is transmitted to the terminal 87B through the **ATM** connection 884.

DETD In this manner, the termination of the **ATM** connection and the network layer protocol processing are carried out three times to transmit the datagram from the terminal 87A to the terminal 87B.

DETD In this case, two **ATM** connections 891 and 892 as shown in FIG. 53 are required, including an **ATM** connection 891 from the terminal 87A of the network 861 to the CLSF 871 of the network 862, and an **ATM** connection from the CLSF 871 to the terminal 87C in the public network 864.

DETD The terminal 87A carries out the **address resolution** of the network layer address of the terminal 87C to recognize that the terminal 87C belongs to the network 851, while also obtains the VCI/VPI data for transmitting the cell to the CLSF 871 in the manner similar to that described above. Then, the datagram is transmitted from this terminal 87A to the CLSF 871 through the **ATM** connection 891.

DETD The datagram and the **ATM** connection are terminated once by the CLSF 871 at which the layer 3 protocol processing for analyzing the network layer address of the datagram is carried out. As a result, it is

recognized that the terminal 87C is present in the network 864, while also obtains the VCI/VPI data for transmitting the cell to the network VCI/VPI. Then, the datagram is transmitted from this CLSF 871 to the IWU provided between the networks 862 and 864 through the **ATM** connection 892.

DETD In this manner, the termination of the **ATM** connection and the network layer protocol processing are carried out once to transmit the datagram from the terminal 87A to the network 864 containing the terminal 87C. Here, the datagram transmission target from the CLSF 871 may be the CLSF provided within the public network 864 if desired. In such a case, the termination of the **ATM** connection and the network layer protocol processing are carried out more than once.

DETD In this case, five **ATM** connections 901 to 905 as shown in FIG. 54 are required, including an **ATM** connection 901 from the terminal 87A to a CLSF 874 within the network 861, an **ATM** connection 902 from the CLSF 874 to a CLSF 871 of the network 862, an **ATM** connection 903 from the CLSF 871 to a CLSF 872 of a sub-network in the network 863 connected with the network 862, an **ATM** connection 904 from the CLSF 872 to a CLSF 873 of a sub-network in the network 863 connected with the terminal 87B, and an **ATM** connection 905 from the CLSF 873 to the terminal 87B.

DETD The terminal 87A carries out the **address resolution** of the network layer address of the terminal 87B to recognize that the terminal 87B belongs to the network 851 (or that the cell is to be transmitted to the CLSF 874), while also obtains the VCI/VPI data for transmitting the cell to the CLSF 874 in the manner similar to that described above. Then, the cell is transmitted from this terminal 87A to the CLSF 874 through the **ATM** connection 901.

DETD The CLSF 874 which received this cell recognizes that there is a need to transmits the cell to the network 862 (or CLSF 871) according to the analysis of the network layer address of the datagram obtained either by the CLSF 874 itself or by the terminal 87A, while also obtains the VCi/VPI data for transmitting the cell to the CLSF 871. Them, the datagram is transmitted from this CLSF 874 to the CLSF 871 through the **ATM** connection 902.

DETD The datagram and the **ATM** connection are terminated once by the CLSF 871 at which the layer 3 protocol processing for analyzing the network layer address of the datagram is carried out. As a result, it is recognized that the terminal 87B is present in the network 863, while also obtains the VCI/VPI data for transmitting the cell to the CLSF 872. Then, the datagram is transmitted from this CLSF 871 to the CLSF 872 through the **ATM** connection 903.

DETD The datagram and the **ATM** connection are terminated again by the CLSF 872 at which the layer 3 protocol processing for analyzing the network layer address of the datagram is carried out, while the VCI/VPI data for transmitting the cell to the CLSF 873 is also obtained. Then, the datagram is transmitted from this CLSF 872 to the CLSF 873 through the **ATM** connection 904.

DETD The CLSF 873 which received the datagram then analyzes the network layer address of the datagram to analyze the access address of the terminal 87B. Then, the cell with the appropriate VCI/VPI attached is transmitted to the terminal 87B through the **ATM** connection 905.

DETD In this manner, the termination of the **ATM** connection and the network layer protocol processing are carried out four (or three) times to transmit the datagram from the terminal 87A to the terminal 87B.

DETD In this case, three **ATM** connections 911 to 913 as shown in FIG. 55 are required, including an **ATM** connection 911 from the

terminal 87A to a CLSF 874 within the network 861, an **ATM** connection 912 from the CLSF 874 to a CLSF 871 of the network 862, and an **ATM** connection 913 from the CLSF 871 to the terminal 87C in the public network 864.

DETD The terminal 87A carries out the **address resolution** of the network layer address of the terminal 87C to recognize that the terminal 87C belongs to the network 851 (or that the cell is to be transmitted to the CLSF 874), while also obtains the VCI/VPI data for transmitting the cell to the CLSF 874 in the manner similar to that described above. Then, the datagram is transmitted from this terminal 87A to the CLSF 874 through the **ATM** connection 911.

DETD The CLSF 874 which received this cell recognizes that there is a need to transmits the cell to the network 862 (or CLSF 871) according to the analysis of the network layer address of the datagram obtained either by the CLSF 874 itself or by the terminal 87A, while also obtains the VCi/VPI data for transmitting the cell to the CLSF 871. Them, the datagram is transmitted from this CLSF 874 to the CLSF 871 through the **ATM** connection 912.

DETD The datagram and the **ATM** connection are terminated once by the CLSF 871 at which the layer 3 protocol processing for analyzing the network layer address of the datagram is carried out. As a result, it is recognized that the terminal 87C is present in the network 864, while also obtains the VCI/VPI data for transmitting the cell to the network VCI/VPI. Then, the datagram is transmitted from this CLSF 871 to the IWU provided between the networks 862 and 864 through the **ATM** connection 913.

DETD In this manner, the termination of the **ATM** connection and the network layer protocol processing are carried out twice (or once) to transmit the datagram from the terminal 87A to the network 864 containing the terminal 87C. Here, the datagram transmission target from the CLSF 871 may be the CLSF provided within the public network 864 if desired. In such a case, the termination of the **ATM** connection and the network layer protocol processing are carried out more than twice.

DETD Now, the embodiment in which the above described **ATM** communication system according to the present invention is applied for a case of realizing a modified network layer topology independent from the topology of the physical network will be described in detail.

DETD FIG. 56 shows a configuration of the **ATM** communication system in this embodiment, which comprises: a first **ATM**-LAN 1101 containing M terminals 151 to 15M and a second **ATM**-LAN 1102 containing N terminals 121 to 12N which are inter-networking through an IWU 1111. Here, the first **ATM**-LAN 1101 has a CLSF 1112 for carrying out the processing for realizing the connection-less communication, whereas the second **ATM**-LAN 1102 has no CLSF.

DETD The CLSF 1112 of the first **ATM**-LAN 1101 not only supports the datagram transmission among the terminals 151 to 15M of the first **ATM**-LAN 1101, but also the datagram transmission among the terminals among the terminals 121 to 12N of the second **ATM**-LAN 1102 as well, and to this end, at the network layer, the CLSF 1112 is given in advance the first address data indicating that it belongs to the first **ATM**-LAN 1101 in which it is physically located, as well as the second address data indicating that it also belongs to the second **ATM**-LAN 1102. These first and second address data will be referred hereafter as the network IDs.

DETD The IWU 1111 inter-networking the first and second **ATM**-LANs 1101 and 1102 has a schematic configuration shown in FIG. 57 which includes a header conversion table 1172 and a header conversion unit

1173, where the header conversion table 1172 registers the relationship between the header (or the connection identifier, i.e., VCI/VPI) of the input cell from the **ATM** connection, and the header of the output cell to the **ATM** connection, while the header conversion unit 1173 converts the header of the input cell by looking up the header conversion table 172 and attaches the converted header to the output cell.

DETD In addition, the first and second **ATM**-LANs 1101 and 1102 have call set up units 1113 and 1114, respectively. The call set up unit 1113 of the first **ATM**-LAN 1101 sets up the **ATM** connections 141 to 14N between the IWU 1111 and the CLSF 1112, as well as the **ATM** connections 161 to 16M between the CLSF 1112 and the terminals 151 to 15M belonging to the first **ATM**-LAN 1101, while the call set up unit 1114 of the second **ATM**-LAN 1102 sets up the **ATM** connections 131 to 13N between the IWU 1111 and the terminals 121 to 12N belonging to the second **ATM**-LAN 1102.

DETD Now, the operation of this embodiment will be described for an exemplary case of realizing the connection-less communication from the terminal 1121 in the second **ATM**-LAN 1102 by using the CLSF 1112 in the first **ATM**-LAN 1101. In this case, the second **ATM**-LAN 1102 containing this terminal 1121 has no CLSF for realizing the connection-less communication itself, so that the CLSF 1112 of the first **ATM**-LAN 1101 is made to be also available for the terminal 1121 of the second **ATM**-LAN 1102 as described below.

DETD First, at the step S11, in order to set up the **ATM** connection between the terminal 1121 and the CLSF 1112, the call set up unit 1114 sets up the first **ATM** connection 1131 between the terminal 1121 and the IWU 1111. Then, at the step S12, the call set up unit 1114 makes the set up request for the **ATM** connection between the IWU 1111 and the CLSF 1112 to the call set up unit 1113 of the first **ATM**-LAN 1101, as the first and second **ATM**-LANs 1101 and 1102 are independent networks. Then, in response to this set up request, at the step S13, the call set up 1113 sets up the **ATM** connection 1141 between the IWU 1111 and the CLSF 1112.

DETD Here, the method of making the **ATM** connection set up request from the call set up unit 1114 to the call set up unit 1113 can be either one of: (1) providing an **ATM** connection 1171 between the call set up unit 1113 and the call set up unit 1114 in advance, and the set up request is made directly through this **ATM** connection 1171, or (2) terminating the set up request from the call set up unit 1114 once at the IWU 1111 and then relaying it to the call set up unit 1113 from the IWU 1111.

DETD When the **ATM** connections 1131 and 1141 are set up in this manner, next at the step S14, the IWU 1111 connects these **ATM** connections 1131 and 1141 at the **ATM** layer. In this case, the header conversion table 1172 has registered entries such that: (a) the header of the cell arriving from the **ATM** connection 1131 is changed to the connection identifier (VCI/VPI) indicating the **ATM** connection 1141, and (b) the header of the cell arriving from the **ATM** connection 1141 is changed to the connection identifier (VCI/VPI) indicating the **ATM** connection 1131. The header conversion unit 1173 converts the header of the arriving cell by looking up this header conversion table 1172, and transmits the cell arriving from the **ATM** connection 1131 to the **ATM** connection 1141, and the cell arriving from the **ATM** connection 1141 to the **ATM** connection 1131. In this manner, the **ATM** connections 1131 and 1141 are connected at the **ATM** layer by the IWU 1111.

DETD Next, at the step S15, the datagram transmission between the terminal

1121 and the CLSF 1112 is carried out through the **ATM** connection 1131 and 1141 connected at the ATM layer. In this case, using the connection between the **ATM** connections 1131 and 1141, the datagram transmission can be realized by simply carrying out the header conversion processing at the **ATM** layer in the IWU 1111, for both of the datagram to be delivered from the terminal 1121 to the CLSF 1112 as well as the **ATM** cell assembled datagram to be delivered from the CLSF 1112 to the terminal 1121.

DETD First, in a case (1) of the datagram transmission from the terminal 1121 to the CLSF 1112, (1-1): the cell assembled datagram is transmitted to the IWU 1111 from the terminal 1121 through the **ATM** connection 1131, (1-2): the IWU 1111 relays the cell arrived from the **ATM** connection 1131 to the **ATM** connection 1141 by looking up the header conversion table 1172, and (1-3): the CLSF 1112 receives the cell assembled datagram arriving from the **ATM** connection 1141.

DETD On the contrary, in a case (2) of the datagram transmission from the CLSF 1112 to the terminal 1121, (2-1): the cell assembled datagram is transmitted to the IWU 1111 from the CLSF 1112 through the **ATM** connection 1141, (2-2): the IWU 1111 relays the cell arrived from the **ATM** connection 1141 to the **ATM** connection 1131 by looking up the header conversion table 1172, and (2-3): the terminal 1121 receives the cell assembled datagram arriving from the **ATM** connection 1131.

DETD In this manner, it is possible in this embodiment to transmit the cell directly at the network layer between the terminal 1121 and the CLSF 1112. The cell transmission between the CLSF 1112 and any of the other terminals 1122 to 112N through the **ATM** connections 1132 to 113N and 1142 to 114N can also be realized similarly.

DETD Next, an exemplary processing at the network layer in this embodiment will be described with reference to FIG. 59 which indicates the physical regions of the **ATM** communication system of FIG. 56 along with the logical regions at the network level and the logical connection states among these logical regions.

DETD Here, between the terminals 1121 to 112N of the second **ATM**-LAN 1102 and the CLSF 1112 of the first **ATM**-LAN 1101, the **ATM** connections 1131 to 113N and 1141 to 114N are provided as in FIG. 56, such that the datagram transmission can be realized in forms of the **ATM** cells between the CLSF1112 and the terminals 1121 to 112N. In addition, the **ATM** connections 1161 to 116M are also provided between the CLSF 1112 and the terminals 1151 to 115M of the first **ATM**-LAN 1101.

DETD The CLSF 1112 has a datagram processing unit 1201 and an **ATM** layer processing unit 1211, and the terminals 1121 to 112N have a data processing unit 1202 and an **ATM** layer processing unit 1212. The datagram processing unit 1201 operates according to the network ID indicating that the CLSF 1112 belongs to the second **ATM**-LAN 1102 with respect to the input and output through the **ATM** connections 1141 to 114N, or according to the network ID indicating that the CLSF 1112 belongs to the first **ATM**-LAN 1101 with respect to the input and output through the **ATM** connections 1161 to 116M.

DETD In this case, the datagram outputted from the datagram processing unit 1202 within the terminals 1121 to 112N is cell assembled at the **ATM** layer processing unit 1212 within the terminals 1121 to 112N, and reaches to the CLSF 1112 without being re-constructed into the datagram form before being cell disassembled at the **ATM** layer processing unit 1211 within the CLSF 1112. Similarly, the datagram outputted from the datagram processing unit 1201 within the CLSF 1112 is

cell assembled at the **ATM** layer processing unit 1211 within the terminals 1121 to 112N, and reaches to the terminals 1121 to 112N without being re-constructed into the datagram form before being cell disassembled at the **ATM** layer processing unit 1212 within the terminals 1121 to 112N.

DETD In this manner, the direct delivery (i.e., the delivery without looking up the network layer data in a middle) of the datagram at the network layer between the terminals 1121 to 112N and the CLSF 1112 is supported, so that there is no need for the datagram processing unit 1202 within the terminals 1121 to 112N to recognize the fact that the CLSF 1112 is actually located in the physically separated first **ATM**-LAN 1101. Similarly, there is no need for the datagram processing unit 1201 within the CLSF 1112 to recognize the fact that the terminals 1121 to 112N are actually located in the physically separated second **ATM** -LAN 1102.

DETD Here, the network layer address is given in a form shown in FIG. 60 in which the network ID described above is multiplexed with the terminal ID indicating the specific address of each terminal. The CLSF 1112 has two sets of network IDs in correspondence to the first and second **ATM**-LANs 1101 and 1102, which are shared with the terminals within the respective **ATM**-LANs 1101 and 1102. It is noted that the order of the network ID and the terminal ID in the network layer address may be reversed from that shown in FIG. 60 if desired.

DETD It is also noted that the scheme for providing two sets of network IDs to be CLSF 1112 with respect to the first and second **ATM**-LANs 1101 and 1102 is adopted in this embodiment because of the easiness of its implementation, but it is also possible to adopt the scheme in which the CLSF 1112 (i.e., the network address belonging to the first **ATM**-LAN 1101 which has the CLSF 1112) can be made to appear as if it is virtually belonging to the second **ATM**-LAN 1102 by operating the CLSF 1112 and the terminals 1121 to 112N accordingly at a time of mapping the **ATM** layer and executing the network layer protocol.

DETD By setting up the network layer address in this manner, it becomes possible at the network layer to handle the CLSF 1112 within the first **ATM**-LAN 1101 as if it is belonging to the second **ATM** -LAN 1102 as well such that the terminals 1121 to 112N and the CLSF 1112 can be treated as if they are belonging to the same network. Namely, the logical region of the second **ATM**-LAN 1102 at the network layer includes the physical region 1221 of the second **ATM**-LAN 1102 as well as the **ATM** connections 1141 to 114N and the CLSF 1112, as indicated by the hatched area in FIG. 59. In this case, the logical region of the first **ATM**-LAN 1101 at the network layer is going to be the physical region of the first **ATM**-LAN 1101 from which the **ATM** connections 1141 to 114N are excluded, so that the CLSF 1112 logically belongs to both of the first and second **ATM** -LANs 1101 and 1102. Here, however, it is to be noted that these logical regions are valid only for the network layer of the connection-less communication (datagram communication), and the logical regions for the **ATM** layer and the logical regions for the network layer of the connection oriented communication are generally different from the logical regions in the connection-less communication.

DETD In this manner, for the connection-less communication, the logical regions at the network layer which is different from the physical regions of the **ATM**-LANs to realize the network layer topology 1231 shown in FIG. 59 in which the CLSF 1112 can be treated as a router (or a gate-way).

DETD Therefore, when the routing protocol is executed among the CLSFs, the CLSF 1112 logically appears at the network layer as if it is located in

the ATM-LAN which physically contains no CLSF. Consequently, even when the already existing routing protocol is executed as it is, the route selected by the routing protocol and the route passing through the CLSF 1112 coincides, so that the consistent connection-less communication can be realized. In this case, it suffices for the IWU 1111 to pass the routing data for the connection-less communication, so that the IWU 1111 can be totally free from the routing in the connection-less communication.

DETD FIG. 61 shows another network topology which can be handled in the manner similar to that described above. In this FIG. 61, three ATM-LANs 1301 to 1303 are inter-networking through IWUs (not shown) with the CLSF 1331, where the CLSF 1331 physically belongs to the ATM-LAN 1301. In this case, by setting up the network layer address in the manner similar to that described above, it becomes possible to make the CLSF 1331 to appear as if it is also logically belonging to the ATM-LANs 1302 and 1303. Consequently, it becomes possible to realize the logical network layer topology in which the ATM-LANs 1301 to 1303 are inter-networking with the CLSF 1331 as a router (or a gate-way).

DETD Now, the manner of executing the routing protocol among the CLSFs in more general case of this embodiment will be described with references to FIGS. 62 and 63. Here, the network configuration of FIG. 56 is expanded such that seven ATM-LANs 1401 to 1407 are inter-networking through six IWUs 1411 to 1416 as shown in FIG. 62, where only the ATM-LANs 1401, 1403, and 1406 contain the CLSFs 1421 to 1423, respectively, while the other ATM-LANs 1402, 1404. 1405, and 1407 have no CLSF physically. Here, however, by setting the network layer addresses as in the above, at the network layer level, the CLSF 1421 logically belongs to the ATM-LAN 1402, the CLSF 1422 logically belongs to the ATM-LAN 1404 and 1405, and the CLSF 1423 logically belongs to the ATM-LAN 1407.

DETD In this case, the ATM connection 1441 is set up between the CLSFs 1421 and 1422, while the IWU 1412 which is inter-networking the ATM-LANs 1401 and 1403 has a function for passing the data as it is with respect to the data transmission including that of the routing data between the CLSFs 1421 and 1422.

DETD Similarly, the ATM connection 1442 is set up between the CLSFs 1421 and 1423, while the IWU 1415 which is inter-networking the ATM-LANs 1401 and 1406 has a function for passing the data as it is with respect to the data transmission including that of the routing data between the CLSFs 1421 and 1423.

DETD Here, a scheme for setting up the ATM connections 1441 and 1442 can be either one of a scheme for setting up one ATM connection for the transmission of the datagram as well as the control data such as the routing data between the CLSFs, or a scheme for setting up different ATM connections for the datagram transmission and the transmission of the control data such as the routing data between the CLSFs.

DETD Namely, the CLSF 1422 notifies the CLSF 1421 that "ATM-LANs 1403, 1404, and 1405 can be reached by one hop" as the ATM -LANs 1403, 1404, and 1405 are the networks to which the CLSF 1422 can deliver the datagram directly. The CLSF 1423 similarly notifies the CLSF 1421 that "ATM-LANs 1406 and 1407 can be reached by one hop" as the ATM-LANs 1406 and 1407 are the networks to which the CLSF 1423 can deliver the datagram directly. Also, the CLSF 1421 notifies the CLSFs 1422 and 1423 that "ATM-LANs 1401 and 1402 can be reached by one hop" as the ATM-LANs 1401 and 1402 are the networks to which the CLSF 1421 can deliver the datagram directly.

DETD In addition, when the routing data from the CLSFs 1422 and 1423 have reached to the CLSF 1421 at this point, the CLSF 1421 notifies the CLSFs

1422 and 1423 that "**ATM**-LANs 1403 to 1407 can be reached by two hops" by adding one hop to the routing data reached from the CLSFs 1422 and 1423.

DETD Here, the CLSFs 1421 to 1423 have associated routing tables 1451 to 1453 which indicate the correspondence relationship between the datagram destination and the delivering target **ATM**-LAN (transmission target) in a case of operating the RIP at the CLSFs 1421 to 1423. Thus, each of the CLSFs 1421 to 1423 calculates the route from the received routing data and selects the shortest route in order to determine the delivering target for the datagram. In the routing tables 1451 to 1451 to 1453, the entry with "direct delivery" registered as the delivery target indicates the network which can be reached by 0 hop.

DETD For example, in a case of the CLSF 1421, the routing table 1451 is constructed according to the routing data indicating that: (1) the **ATM**-LANs 1401 and 1402 can be delivered directly by itself, (2) the **ATM**-LANs 1403, 1404, and 1405 can be reached by one hop from the CLSF 1422, and (3) the **ATM**-LANs 1406 and 1407 can be reached by one hop from the CLSF 1423.

DETD For example, in a case of the CLSF 1422, the routing table 1452 is constructed according to the routing data indicating that: (1) the **ATM**-LANs 1403, 1404, and 1405 can be delivered directly by itself, (2) the **ATM**-LANs 1401 and 1402 can be reached by one hop from the CLSF 1421, and (3) the **ATM**-LANs 1403, 1404. 1405, 1406, and 1407 can be reached by two hops from the CLSF 1421. Here, for the **ATM**-LANs 1403, 1404, and 1405, the directly delivering route is going to be the shortest route, so that the directly delivering route is registered in the routing table 1452.

DETD For example, in a case of the CLSF 1423, the routing table 1453 is constructed according to the routing data indicating that: (1) the **ATM**-LANs 1406 and 1407 can be delivered directly by itself, (2) the **ATM**-LANs 1401 and 1402 can be reached by one hop from the CLSF 1421, and (3) the **ATM**-LANs 1403, 1404, 1405, 1406, and 1407 can be reached by two hops from the CLSF 1421. Here, for the **ATM**-LANs 1406 and 1407, the directly delivering route is going to be the shortest route, so that the directly delivering route is registered in the routing table 1453.

DETD The procedure for carrying out the connection-less communication over the **ATM**-LANs using these routing tables 1451 to 1453 will be described with reference to FIG. 63, for an exemplary case of the datagram transmission from the terminal 1461 belonging to the **ATM**-LAN 1404 to the terminal 1462 belonging to the **ATM** -LAN 1407. In this case, by the call set up units provided in the networks, the **ATM** connection 1443 between the terminal 1461 and the CLSF 1422 and the **ATM** connection 1444 between the terminal 1462 and the CLSF 1423 are set up in advance in the manner described above.

DETD At the terminal 1461, the data from the application is processed to obtain the datagram to be transmitted to the terminal 1462 at the datagram processing unit 4611, and the cell is assembled from the datagram at the cell assembling unit 4612, and the assembled cell is outputted from the cell transmission unit 4613. The cell outputted from the terminal 1461 then reaches to the CLSF 1422 through the **ATM** connection 1443.

DETD At the CLSF 1422, the arrived cell is received at the cell reception unit 4221, and the cell is disassembled at the cell disassembling unit 4222, and the datagram is reproduced at the datagram processing unit 4223, and then the network ID of the transmission target given in a form shown in FIG. 60 is transmitted to the routing protocol execution unit 4224. At the routing protocol execution unit 4224, according to this network ID, it can be recognized that the terminal 1462 belongs to the **ATM**-LAN 1407, so that the routing table 1452 is looked up to determine the delivery target as the CLSF 1421. Then, the **ATM**

address search unit 4225 looks up the **ATM** address table 1472 according to the network ID of the CLSF 1421 to obtain the VCI/VPI value appropriate for the datagram transmission to the CLSF 1421, and transmits the obtained VCI/VPI value to the cell assembling unit 4226. The cell assembling unit 4226 then assembles the cell from the payload including the datagram transmitted from the datagram processing unit 4223 according to the routing data supplied from the routing protocol execution unit 4224 and the VCI/VPI value supplied from the **ATM** address search unit 4225, and the assembled cell is outputted from the cell transmission unit 4227.

DETD The cell outputted from the CLSF 1422 is then transmitted to the CLSF 1421 through the **ATM** connection 1441 and the IWU 1412 provided between the CLSFs 1421 and 1422. The IWU 1412 only applies the **ATM** layer processing (which is the processing requiring no cell re-assembling) to the cell from the CLSF 1422 and pass it to the CLSF 1421.

DETD At the CLSF 1421, the processing similar to that carried out at the CLSF 1422 is carried out, and the routing table 1451 is looked up to determine the delivery target as the CLSF 1423. Then, the cell is assembled by obtaining the appropriate VCI/VPI value from the **ATM** address table 1471, and the assembled cell is outputted to the CLSF 1423. The cell outputted from the CLSF 1421 is then transmitted to the CLSF 1423 through the **ATM** connection 1442 and the IWU 1415 provided between the CLSFs 1421 and 1423.

DETD At the CLSF 1423, the processing similar to that carried out at the CLSF 1421 is carried out, and the routing table 1453 is looked up to recognize that the delivery target can be delivered directly (as the CLSF 1423 itself is registered as the delivery target by the RIP), i.e., the destination is the terminal 1462 which is directly connected by the **ATM** connection from the CLSF 1423. Then, by looking up the **ATM** address table 1473, the **ATM** connection 1444 is registered In correspondence to the terminal 1462, so that the CLSF 1423 outputs the cell assembled from the datagram to the terminal 1462 through the **ATM** connection 1444. The cell outputted from the CLSF 1423 is then transmitted to the terminal 1462 through the **ATM** connection 1444 and the IWU 1416 provided between the CLSF 1423 and the terminal 1462.

DETD At the terminal 1462, the cell arriving through the **ATM** connection 1444 is received at the cell reception unit 4621, the cell is disassembled at the cell disassembling unit 4622, and the datagram is reconstructed at the datagram processing unit 4623, and the re-constructed datagram is transmitted to the application.

DETD In this manner, the datagram transmission over the **ATM**-LANs using the routing protocol can be realized. Here, as for the routing protocol which is operated among the CLSFs, the the routing data is cell assembled by the routing protocol execution unit within the CLSF, while also supplied to the other CLSFs connected though the **ATM** connections, and the CLSF which received the routing data re-constructs the datagram at the datagram processing unit within the CLSF, and transmits the routing data to the routing protocol execution unit.

DETD Next, a scheme for transmitting the routing data from the CLSF to the **ATM**-LAN in which the CLSF is absent will be described with reference to FIG. 64, the **ATM**-LANs 1501 and 1502 are inter-networking through the IWU 1511, where the **ATM**-LAN 1501 has the CLSF 1521 while the **ATM**-LAN 1502 has no CLSF. Here, the CLSF 1521 is logically connected with the **ATM**-LAN 1502 as in the above such that the CLSF 1521 can appear to be logically present

in the **ATM**-LAN 1502 as well. Although not shown in FIG. 64, the **ATM**-LANs 1501 and 1502 are also connected with the other **ATM**-LANs through the IWUs, and the CLSF 1521 is executing the routing protocol.

DETD The CLSF 1521 transmits the routing data to the device 1531 which requires the routing data within the **ATM**-LAN 1501 in which the CLSF 1521 is contained as well as to the device 1532 which requires the routing data within the **ATM**-LAN 1502 which logically belongs to the same network as the **ATM**-LAN 1501. Here, the devices 1531 and 1532 which require the routing data can be any of the datagram terminals, the **address resolution server** (ARS) for setting a correspondence between the network ID and the VCI/VPI, and the IWU.

DETD In this case, the routing data to the device 531 can be delivered from the CLSF 1521 as it is within the **ATM**-LAN 1501 as this device 1531 is located within the **ATM**-LAN 1501 in which the CLSF 1521 is also located.

DETD On the other hand, in order to deliver the routing data from the CLSF 1521 to the **ATM**-LAN 1502, it suffices for the IWU 1511 provided between the CLSF 1521 and the **ATM**-LAN 1502 to pass the routing data transmitted from the CLSF 1521 to the device 532 as it is, because there is no need to process the routing data as the CLSF 1521 also belongs to the **ATM**-LAN 1502 at the network layer. To this end, there is a need for the CLSF 1521 and the device 1532 to be connected at the **ATM** layer even when the IWU 151 is located therebetween. This can be achieved by using the **ATM** connection for the logical connection as in the above, or by setting up the separate **ATM** connection for the routing data transmission.

DETD As an example, a case of using the RIP described above will be described. In this case, as shown in FIG. 64, the CLSF 1521 has the routing table 1541, and the devices 1531 and 1532 which require the routing data are executing the RIP to make the passive operation (i.e., the operation in which the routing data is received and processed, but not transmitted to the others). In this case, according to the routing data received from the CLSF 1521, the device 1531 within the **ATM** -LAN 1501 can construct the routing table 1551, while the device 1532 within the **ATM**-LAN 1502 can construct the routing table 1552.

DETD When these routing tables 1551 and 1552 are constructed, they can function as means for selecting the direct datagram transmission without passing through CLSF when the destination terminal is located within the same **ATM**-LAN.

DETD Now, FIG. 65 shows another configuration of the **ATM** communication system in this embodiment, which comprises: a first **ATM**-LAN 1601 containing N terminals 1631 to 163N, a second **ATM**-LAN 1602 containing N terminals 1641 to 164N, and a third **ATM**-LAN 1603 containing N terminals 1651 to 165N, where the first and second **ATM**-LANs 1601 and 1602 are inter-networking through an IWU 1611, and the second and this **ATM**-LANs 1602 and 1603 are inter-networking through an IWU 1612. Here, the first **ATM**-LAN 1601 has a CLSF 1613 for carrying out the processing for realizing the connection-less communication, whereas the second and third **ATM**-LANs 1602 and 1603 have no CLSF.

DETD In addition, the **ATM**-LANs 1601, 1602, and 1603 have call set up units 1616, 1615, and 1614, respectively. The call set up unit 1113 of the first **ATM**-LAN 1101 sets up the **ATM** connections 141 to 14N between the IWU 1111 and the CLSF 1112, as well as the **ATM** connections 161 to 16M between the CLSF 1112 and the terminals 151 to 15M belonging to the first **ATM**-LAN 1101, while the call set up unit 1114 of the second **ATM**-LAN 1102 sets up the **ATM** connections 131 to 13N between the IWU 1111 and the terminals 121 to 12N belonging to the second **ATM**-LAN 1102.

DETD The CLSF 1613 of the first **ATM**-LAN 1601 not only supports the

datagram transmission among the terminals (not shown) of the first ATM-LAN 1601 but also the datagram transmission among the terminals among the terminals (not shown) of the second ATM -LAN 1602 and the datagram transmission among the terminals among the terminals 1621 to 162N as well, and to this end, at the network layer, the CLSF 1112 is given not only the first network ID indicating that it belongs to the first **ATM**-LAN 1601 in which it is physically located, as well as the second and third network IDs indicating that it also belongs to the second and third **ATM**-LANs 1602 and 1603. In this manner, the CLSF 1613 can be made to appear as if it is in the second **ATM**-LAN 1602 or the third **ATM**-LAN 1603.

DETD In this case, the connection-less communication (datagram transmission) between the CLSF 1613 and the terminals 1621 to 162N in the **ATM** -LAN 1603 requires the passing through two IWUs 1611 and 1612. This operation will now be described.

DETD Here, as described above, the **ATM**-LAN 1603 has no CLSF, so that it is necessary to make the CLSF 1613 in the **ATM**-LAN 1601 to be available to the terminals in the **ATM**-LAN 1603. In the following, an exemplary case of the datagram transmission from the terminal 1621 in the **ATM**-LAN 1603 will be described.

DETD First, at the step S21, in order to set up the **ATM** connection between the terminal 1621 and the CLSF 1613, the call set up unit 1614 sets up the **ATM** connection 1631 between the terminal 621 and the IWU 1612. Then, at the step S22, the call set up unit 1614 makes the **ATM** connection set up request to the call set up unit 1615 in the **ATM**-LAN 1602 which is the independent network from the **ATM**-LAN 1603 to which the call set up unit 1614 belongs.

DETD Here, however, the **ATM**-LAN 1602 also has no CLSF, so that the call set up request unit 1615 which received the **ATM** connection set up request from the call set up unit 1614 sets up the **ATM** connection 1641 between the IWU 1612 and the IWU 1611 at the step S23, and makes the call set up request for the CLSF 1613 to the call set up unit 1616 in the neighboring **ATM**-LAN 1601 at the step S24. Then, the call set up unit 1616 sets up the **ATM** connection 1651 between the IWU 1611 and the CLSF 1613 in response to the received call set up request at the step S25.

DETD When the **ATM** connections 1631, 1641, and 1651 are set up in this manner, next at the step S26, the IWU 1612 connects the **ATM** connections 1631 and 1641 at the **ATM** layer, while the IWU 1611 connects the **ATM** connections 1641 and the 1651 at the **ATM** layer in the same manner as in the above.

DETD Then, at the step S27, the datagram transmission between the terminal 1621 and the CLSF 1613 is carried out through the **ATM** connections 1631, 1641, and 1651 connected at the **ATM** layer in terms of the **ATM** cells.

DETD The similar procedure can also be followed for the other terminals 1622 to 162N, to set up the **ATM** connections 1632 to 163N 1642 to 164N, and 1652 to 165N, connect the **ATM** connections 1632 to 163N and the **ATM** connections 1642 to 164N at the IWU 1612, connect the **ATM** connections 1642 to 164N and the **ATM** connections 1852 to 165N at the IWU 1611, and carry out the datagram transmissions in terms of the **ATM** cells between the terminals 1622 to 162N to the CLSF 1613.

DETD By setting up the **ATM** connections in this manner, it becomes possible to carry out the direct datagram delivery at the network layer between the terminals 1621 to 162N and the CLSF 1613.

DETD Thus, by setting the **ATM** connections between the terminals 1621 to 162N and the CLSF 1613, and assigning the network ID for the **ATM**-LAN 1603 to the CLSF 1613 as well, it becomes possible to realize the connection-less communication between the **ATM**-LANs which are logically connected over more than one IWUs.

DETD Next, another embodiment in which the above described **ATM** communication system according to the present invention is applied for a

case of realizing a modified network layer topology independent from the topology of the physical network will be described in detail.

DETD FIG. 67 shows a configuration of the **ATM** communication system in this embodiment, which comprises: first, second, and third **ATM**-LANs 1701, 1702, and 1703, where the first and second **ATM**-LANs 1701 and 1702 are inter-networking through an IWU 1711 while the second and third **ATM**-LANs 1702 and 1703 are inter-networking through an IWU 1712. Here, the first and second **ATM**-LANs 1701 and 1702 have CLSFs 1721 and 1722, respectively, whereas the third **ATM**-LAN 1703 has no CLSF.

DETD The third **ATM**-LAN 1703 is logically connected with the CLSF 1722 in the second **ATM**-LAN 1702 as indicated by a logical connection 1731 in the same manner as in the above. Moreover, the third **ATM**-LAN 1703 is also logically connected with the CLSF 1721 in the first **ATM**-LAN 1701 which is separated by more than one hops in terms of the number of the IWUs as indicated by a logical connection 1732 tunnelling through the IWUs 1711 and 1712, as in the case of FIG. 65 described above. Thus, the third **ATM**-LAN 1703 logically has two CLSFs.

DETD The CLSF 1721 has the **ATM**-LANs 1701 and 1703 as the networks to which it can make the direct delivery, so that it notifies the CLSF 1722 that "**ATM**-LANs 1701 and 1703 can be reached by one hop". The CLSF 1722 has the **ATM**-LANs 1702 and 1703 as the networks to which it can make the direct delivery, so that it notifies the CLSF 1721 that "**ATM**-LANs 1702 and 1703 can be reached by one hop".

DETD By this data exchange, the routing table 1751 is constructed at the CLSF 1721 and the routing table 1752 is constructed at the CLSF 1722. In addition, the **ATM**-LAN 1703 eventually receives the routing data indicating that "**ATM**-LAN 1701 can be reached by one hop" and "**ATM**-LAN 1702 can be reached by two hops" from the CLSF 1721, as well as the routing data indicating that "**ATM**-LAN 1701 can be reached by two hops" and "**ATM**-LAN 1702 can be reached by one hop" from the CLSF 1722. Then, the device 1741 in the **ATM**-LAN 1703 which is making the passive operation can construct the routing table 1753 indicating that "the datagram destined to the **ATM**-LAN 1701 should be transmitted to the CLSF 1721" and "the datagram destined to the **ATM**-LAN 1702 should be transmitted to the CLSF 1722" according to these routing data received by the **ATM**-LAN 1703.

DETD As for the other **ATM**-LANs 1701 and 1702, each of them has only one CLSF connected, so that there is no choice of the CLSFs available. However, each of them can be modified to provide the choice of the CLSFs similarly to the **ATM**-LAN 1703 by providing the logical connection between the **ATM**-LAN 1702 and the CLSF 1721 or the logical connection between the **ATM**-LAN 1701 and the CLSF 1722, if desired.

DETD Now, a scheme for setting up the **ATM** connection between the IWU and the CLSF in this embodiment will be described with reference to FIG. 68. In this case, the **ATM**-LANs 1801 and 1802 are inter-networking through the IWU 1811, and the **ATM**-LAN 1801 contains the CLSF 1821, while the **ATM**-LAN 1802 is logically connected with the CLSF 1821 in the **ATM**-LAN 1801 as in the above.

DETD Between the CLSF 1821 and the IWU 1811, as many **ATM** connections (which define VCs) 1831 to 183N as a number N of terminals belonging to the **ATM**-LAN 1802 are set up. By bundling these VCs 1831 to 183N together as one VP 1841, it becomes possible for the **ATM**-LAN 1801 to realize the cell transmission between the CLSF 1821 and the IWU 1811 by only looking up the 8 bits VPI indicating the VP 1841, without looking up the 16 bits VCI.

DETD In addition, by directly connecting each connection of the VCs 1831 to 183N in the VP 1841 with the already established **ATM**

connection (not shown) between the IWU 1811 and the terminal in the **ATM**-LAN 18[illegible] at the **ATM** layer by the IWU 18[illegible] the cell transmission from the terminal in the **ATM**-LAN 1802 to the CLSF 1821 can be realized as the IWU 1811 carries out the relaying of the cell from the **ATM** connection 1851 to the **ATM** connection given by one of the VCs 1831 to 183N in the VP 1841. In addition, for the cells transmitted from the CLSF 1821 to the terminal in the **ATM**-LAN 1802, the IWU 1811 also carries out the relaying of the cell for the **ATM** connection between the IWU 1811 and the terminal in the **ATM**-LAN 1802 by looking up the VCI field, to realize the cell transmission between the CLSF 1821 and the terminal in the **ATM**-LAN 1802 in a case of using the bundling of the VCs 1831 to 183N into the VP 841.

DETD Next, a scheme for setting up the **ATM** connection between the IWU and the CLSF in this embodiment in a case of involving the connection between the **ATM**-LANs which are separated by more than one hops in terms of the number of IWUs will be described with reference to FIG. 69. In this case, the **ATM**-LANs 1901, 1902, and 1903 are provided, where the **ATM**-LANs 1901 and 1902 are inter-networking through the IWU 1911 while the **ATM**-LANs 1902 and 1903 are inter-networking through the IWU 1912, and the **ATM**-LAN 1901 contains the CLSF 1921, while the **ATM**-LANs 1902 and 1903 are logically connected with the CLSF 1921 in the **ATM**-LAN 1901 as in the above.

DETD Between the CLSF 1921 and the IWU 1911, as many **ATM** connections which define VCs 1931 to 193M as a number M of terminals belonging to the **ATM**-LAN 1902 are set up, along with as many **ATM** connections which define VCs 1941 to 194N as a number N of terminals belonging to the **ATM**-LAN 1903.

DETD By bundling these VCs 1931 to 193M and 1941 to 194N together as one VP 1941, it becomes possible for the **ATM**-LAN 1901 to exchange the datagrams destined to the **ATM**-LANs 1902 and 1903 which are outputted from the CLSF 1921 to the IWU 1911 and the datagrams from the terminals in the **ATM**-LANs 1902 and 1903 by the 8 bits VPI indicating the VP 1951.

DETD In addition, the terminals in the **ATM**-LAN 1902 and the VCs 1931 to 193M bundled into the VP 1951 set up between the the IWU 1911 and the CLSF 1921, as well as the VCs 1961 and 196N set up between the IWUs 1911 and 1912 and the VCs 1941 to 194N bundled into the VP 1951 are directly connected at the **ATM** layer by the IWU 1911. For this reason, for the VP 1951, the IWU 1911 sets whether it is the tunnelling to the IWU 1912 or the delivery to the **ATM**-LAN 1902, according to the VCI values of those which have arrived from the CLSF 1921. Also, for those which have arrived from the terminals in the **ATM**-LAN 1902, the IWU 1911 is set to carry out the relaying of the cells to the connection (not shown) between the terminals in the **ATM**-LAN 1902 and the IWU 1911 and the **ATM** connections indicated by the VP 1951 and the VCs 1931 to 193M, and for those which have arrived from the IWU 1912, the IWU 1911 is set to carry out the relaying of the cells to the VP 1951 and the VCs 1941 to 194N.

DETD By these settings, in a case of involving the connection of the **ATM**-LANs which are separated by more than one hops in terms of the number of IWUs, the **ATM** connections between the CLSF 1921 and the IWU 1911 can be bundled together.

DETD Similarly, in the **ATM**-LAN 1902, for those which are to be tunnelled to the IWU 1912 among the above described VCs, by bundling the VCs 1961 to 196N in the **ATM**-LAN 1902 into one VP 1952, they can be exchanged with the IWU 1912 by only looking up the 8 bits VPI indicating the VP 1952.

DETD Next, a method for judging whether it is the tunnelling to the IWU 1912 or the delivery to the terminals in the **ATM**-LAN 1902 will be described.

DETD The upper P bits 1972 of the VCI indicating the VCs 1931 to 193M and the VCs 1941 to 194N between the IWU 1911 and the CLSF 1921 are used as the network identification, and set up such that it is possible to judge whether it is the delivery to the terminals in the **ATM**-LAN 1902 or the tunnelling to the IWU 1912 according to the value of these VCI upper P bits 1972 at the IWU 1911. In a case of the delivery to the **ATM**-LAN 1902, they are converted into the VCI/VPI between the IWU 1911 and the terminals in the **ATM**-LAN 1902 by the VCI lower (18-P) bits 1973 and the cell is outputted to the terminals. Namely, the transmission target terminal is identified according to the VCI lower (16-P) bits 1973. In a case of the tunnelling to the IWU 1912, the cell is outputted to the VP for the tunnelling to the IWU 1912. Here, for the VCI value, any of (1) changing only the upper P bits of the VCI, (2) changing all of the VCI, and (3) not changing the VCI, can be selected appropriately.

DETD For the cell arriving from the terminals in the **ATM**-LAN 1902, the relaying of the cells to the **ATM** connections indicated by the VCs 1931 to 193M in the VP 1951 is carried out at the IWU 1911. In this case, the **ATM** connections set up between the IWU 1911 and the terminals in the **ATM**-LAN 1902 and the VCs 1931 to 193M are directly connected in the IWU 1911. At this point, the header value to be assigned to the VCs 1931 to 193N may be the same value or the different value as the value of the **ATM** connection from the CLSF 1921 to the IWU 1911.

DETD As for the cell transmitted from the IWU 1912 to the IWU 1911, the relaying of the cells to the **ATM** connections indicated by the VCs 1941 to 194N in the VP 1951 is carried out at the IWU 1911. At this point, the value of the VCs 1941 to 194N may be the same value or the different value as the value of the **ATM** connection from the CLSF 1921 to the IWU 1911.

DETD As for the cells which are tunnelled, by using the format of the cell header 1971 in the **ATM**-LAN 1902, and carrying out the same processing as the IWU 1911 at the IWU 1912, the IWU can pass the cell by the same processing for the networks which are separated by more than two hops in terms of the number of IWUs.

DETD Here, the VCI upper P bits 1972 can have an optional number of bits P, and the number of **ATM**-LANs that can be contained and the number of terminals in the **ATM**-LAN without the CLSF are varied according to the value of P. In a case the connections between the IWU and the CLSF are bundled into one VP, the number of terminals to which the CLSF can make the direct delivery is going to be 2.sup.16 regardless of the value of P.

DETD Next, a method of carrying out the broadcast between the CLSF and the **ATM**-LANs which are logically connected with CLSF as in the above will be described with reference to FIG. 71.

DETD In FIG. 71, the **ATM**-LANs 1001 and 1002 are inter-networking through the IWU 1011, and the **ATM**-LAN 1001 contains the CLSF 1021, while the **ATM**-LAN 1002 is logically connected with the CLSF 1021 as in the above, and as many **ATM** connections 1031 as the number of terminals belonging to the **ATM**-LAN 1002 are provided as the **ATM** connections between the CLSF 1021 and the IWU 1011. In addition, the **ATM** connection 1041 for broadcast is also provided, and this **ATM** connection 1041 is directly connected at the **ATM** layer to the broadcast channel at the **ATM**-LAN 1002.

DETD In a case the CLSF 1021 makes the broadcast with respect to the **ATM**-LAN 1002, first the CLSF 1021 transmits the broadcast cell to the **ATM** connection 1041 for broadcast. This **ATM** connection 1041 is not for the broadcast in the **ATM**-LAN 1001, so that the broadcast is not carried out in the **ATM**-LAN 1001. At the IWU 1011, the cells transmitted from the **ATM** connection

1041 for broadcast are outputted to the broadcast channel of the **ATM**-LAN 1002. By this, the the cells in the **ATM**-LAN 1002 is broadcasted through the broadcast channel in the **ATM** -LAN 1002.

DETD On the other hand, as for the broadcast cells generated from the terminals in the **ATM**-LAN 1002, the broadcast cells may be made to arrive at the CLSF 1021 as well by outputting them to the **ATM** connection 1041 for broadcast at the IWU 1011.

DETD By this method, the transmission and reception of the broadcast cells between the CLSF 1021 and the **ATM**-LAN 1002 can be realized without loading the **ATM**-LAN 1001 which contains the CLSF 1021.

DETD Next, a method of carrying out the broadcast between the CLSF and the **ATM**-LANs which are logically connected with CLSF and separated by more than one hops in terms of the number of IWUs will be described with reference to FIG. 72.

DETD In FIG. 72, the **ATM**-LANs 2101 and 2102 are inter-networking through the IWU 2111, and the **ATM**-LANs 2102 and 2103 are inter-networking though the IWU 2112. The **ATM**-LAN 2101 contains the CLSF 2121, while the **ATM**-LANs 2102 and 2103 are logically connected with the CLSF 2121 as in the above.

DETD Between the CLSF 2121 and the IWU 2111, as many **ATM** connections (not shown) as the number of terminals belonging to the **ATM**-LAN 2102 are set up, and between the CLSF 2121 and the IWU 2111 and between the IWU 2111 and the IWU 2112, as many **ATM** connections 2131 and 2141, respectively, as the number of the terminals belonging to the **ATM**-LAN 2103 are set up, where the **ATM** connections 2131 and 2141 are directly connected at the **ATM** layer by the IWU 2111.

DETD In addition, the **ATM** connection 2161 for broadcast is provided between the IWUs 2111 and 2112, and the **ATM** connection 2151 for broadcast is provided between the IWU 2111 and the CLSF 2121, where these **ATM** connections 2161 and 2151 are directly connected at the **ATM** layer by the IWU 2111. Also, the **ATM** connection 2161 for the broadcast in the **ATM**-LAN 2103 is directly connected with the broadcast channel In the **ATM**-LAN 2103 at the **ATM** layer by the IWU 2112.

DETD In a case the CLSF 2121 makes the broadcast with respect to the **ATM**-LAN 2103, the CLSF 2121 transmits the broadcast cell to the IWU 2111 through the **ATM** connection 2151 for broadcast in the **ATM**-LAN 2103. Here, the broadcast is not made in the **ATM** -LAN 2101 as there is no broadcast channel in the **ATM**-LAN 2101.

DETD At the IWU 2111, the relaying of the cells to the IWU 2112 is carried out by using the **ATM** connection 2161 for broadcast in the **ATM**-LAN 2103. At the IWU 2112, the cells transmitted from the **ATM** connection 2161 for broadcast are outputted to the broadcast channel of the **ATM**-LAN 2103, so as to realize the broadcast through the broadcast channel in the **ATM**-LAN 2103.

DETD On the other hand, as for the cells broadcasted at the terminals in the **ATM**-LAN 2103, the cells are transmitted to the IWU 2111 by using the **ATM** connection 2161 for broadcast which is set up between the IWUs 2112 and 2111 by the IWU 2112. In addition, the cells may be transmitted to the CLSF 2121 by using the **ATM** connection 2151 for broadcast which i set up between the IWU 2111 and the CLSF 2121 by the IWU 2111.

DETD By this method, the transmission and reception of the broadcast cells can be realized without loading the CLSF 2121, the **ATM**-LAN 2101 in which the CLSF 2121 is contained, and the **ATM**-LAN 2102 to be tunnelled.

DETD It is noted that, in the above description, the state of being directly connected at the **ATM** layer can be equivalently expressed as a state of being able to transmit the cell without carrying out the AAL ( **ATM** Adaptation Layer) processing. In addition, in the above description, the address data at the network layer can be replaced by the address data at the CL (Connection-Less) layer, i.e., the upper

layer of the AAL if desired.

CLM What is claimed is:

1. An **ATM** communication system, comprising: a plurality of networks, including **ATM** networks and a destination side network and containing a plurality of terminals, the plurality of networks inter-networking with each other, the destination side network containing a destination terminal; and a plurality of connection-less service function means for managing connection-less datagram transmission in the plurality of networks, the plurality of connection-less service function means including a destination side connection-less service function means which is associated with the destination side network; wherein the connection-less datagram transmission from each terminal of the plurality of terminals to the destination terminal is performed by obtaining a connection identifier for identifying an **ATM** connection connected to the destination side connection-less service function means, and by transmitting a datagram from said each terminal to the destination side connection-less service function means through the **ATM** connection identified by the obtained connection identifier.

2. The system of claim 1, wherein the destination side network is an **ATM** network and the connection-less service function means is provided in each **ATM** network separately.

3. The system of claim 1, wherein the **ATM** connection is set up between said each terminal and the destination side connection-less service function means.

4. The system of claim 1, wherein the **ATM** connection is set up between a source side connection-less service function means associated with a source side **ATM** network containing said each terminal and the destination side connection-less service function means.

6. The system of claim 4, further comprising: inter-networking means provided in the **ATM** networks for inter-networking the **ATM** networks, for setting up the **ATM** connection between the source side connection-less service function means and the destination side connection-less service function means.

8. The system of claim 1, wherein the destination side connection-less service function means terminates the **ATM** connection to analyze the datagram transmitted from said each terminal and relays the datagram in the destination side network to the destination terminal.

10. The system of claim 1, wherein the connection identifier is obtained by using an **ATM** layer address of the destination side connection-less service function means at said each terminal.

11. The system of claim 1, wherein the connection identifier is obtained by using an **ATM** layer address of the destination side connection-less service function means at a source side connection-less service function means associated with a source side network containing said each terminal.

12. The system of claim 1, further comprising; inter-networking means provided in the **ATM** networks for inter-networking the **ATM** networks, for setting up the **ATM** connection between said each terminal and the destination side connection-less service function means, which is not terminated over the inter-networking means.

13. The system of claim 1, further comprising: **address**

**resolution server** provided for each **ATM** network for processing an **address resolution** request from said each **ATM** network by relaying the **address resolution** request to another **address resolution server** for another **ATM** network when a target of the **address resolution** request does not belong to said each **ATM** network, and returning information indicative of the connection identifier of an **ATM** connection which is connected to the destination side connection-less service function means, to said each **ATM** network.

16. The system of claim 1, wherein the **ATM** networks are given in forms of **ATM**-LANs.

17. The system of claim 1, wherein the connection identifier is given

in

terms of VCI/VPI value specifying the **ATM** connection.

18. The system of claim 1, wherein the **ATM** networks are arranged in a hierarchical network topology.

19. The system of claim 1, wherein the **ATM** networks are arranged in a flat network topology.

20. A method for **ATM** communication in an **ATM** communication system formed by a plurality of networks, including **ATM** networks and and containing a plurality of terminals, the plurality of networks inter-networking with each other, the destination side network including a destination terminal, and a plurality of connection-less service function means for managing connection-less datagram transmission in the plurality of networks, the plurality of connection-less service function means including a destination side connection-less service function means which is associated with the destination side network, the method comprising the steps of: obtaining a connection identifier for identifying an **ATM** connection connected to the destination side connection-less service function means; and transmitting a datagram from each terminal of the plurality of terminals to the destination side connection-less service function means through the **ATM** connection identified by the obtained connection identifier so as to perform the connection-less datagram transmission from said each terminal to the destination terminal.

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AB Asynchronous Transfer Mode Local Area Network (**ATM** LAN). The **ATM** LAN is implemented as a set of **MAC** entities which share a common group address space for the purposes of establishing multicast connections. Each station has one or more **ATM** **MAC** entities per physical connection to an **ATM** network. The network **ATM** LAN service provides the station with **ATM** LAN configuration information needed for **ATM** **MAC** operation. Included in this information is the number of **ATM** LANs the network has configured for that station.

SUMM Title: METHOD AND APPARATUS FOR REACTIVE CONGESTION CONTROL IN AN ASYNCHRONOUS TRANSFER MODE (**ATM**) NETWORK

SUMM Title: CONCURRENT MULTI-CHANNEL SEGMENTATION AND REASSEMBLY PROCESSORS FOR ASYNCHRONOUS TRANSFER MODE (**ATM**)

SUMM In the above-identified application CONCURRENT MULTI-CHANNEL SEGMENTATION AND REASSEMBLY PROCESSORS FOR ASYNCHRONOUS TRANSFER MODE ( **ATM**) an apparatus for concurrently processing packets in an asynchronous transfer mode (**ATM**) network is described. Packets that are to be transmitted are segmented into a plurality of cells, concurrently for a plurality of channels, and the cells are transmitted over an asynchronous transfer mode (**ATM**) channel. Cells received from the asysnchronous transfer mode (**ATM**) channel are reassembled into packets concurrently for the plurality of channels.

SUMM The present invention is an Asynchronous Transfer Mode Local Area Network (**ATM** LAN). The **ATM** LAN is implemented as a set of **MAC** entities which share a common group address space for the purposes of establishing multicast connections. Each station has

one or more **ATM** **MAC** entities per physical connection to an **ATM** network. The network **ATM** LAN service provides the station with **ATM** LAN configuration information needed for **ATM** **MAC** operation. Included in this information is the number of **ATM** LANs the network has configured for that station.

SUMM In the present invention, a communication system includes an **ATM** network. The **ATM** network has a plurality of ports, each port having a unique port address. The **ATM** network includes one or more **ATM** switches for connecting sending ports to receiving ports.

SUMM The communication system includes a plurality of stations, each station having a unique station address distinguishing the station from other stations. Each station is connected to the **ATM** network at a port whereby source stations communicate with destination stations. Each

station provides packets for transferring information, information including a destination station address, for addressing destination stations. Each station includes a packet converter for converting between packets and cells for transfers between stations.

SUMM The communication system provides **address resolution** for determining a port address corresponding to a destination station address. The **address resolution** includes multicast

for multicasting the destination station address to a group of stations.

SUMM The communication system provides management for requesting connections through the **ATM** network connecting sending ports to receiving ports whereby packets are transferred from source stations to destination stations by cell transfers through **ATM** network.

SUMM **ATM** LANs may are extended by bridging several **ATM** LANs together using transparent **MAC** bridges and routers.

SUMM The communication system operates with a multi-level architecture, such as the ISO architecture, and Logical Link Control (LLC), Media Access Control (**MAC**) and addressing functions are performed for **ATM** LANs. An **ATM** LAN provides support for the LLC sublayer by means of a connectionless **MAC** sublayer service in a manner consistent with other IEEE 802 local and metropolitan area networks. The **ATM** LAN interface is built on the user-to-network interface for **ATM** and adaptation layers.

SUMM The communication system including the **ATM** LAN provides the following benefits:

DRWD FIG. 1 depicts a number of user stations connected together in an **ATM** network system.

DRWD FIG. 2 depicts the multi-level protocol used to connect two or more stations in the **ATM** network system of FIG. 1.

DRWD FIG. 3 depicts the network layer and the data link layer connected to a **ATM** interface in the **ATM** network system of FIGS. 1 and 2.

DRWD FIG. 4 depicts details of the **ATM MAC** sublayer and the **ATM** interface for stations of FIGS. 1 and 2.

DRWD FIG. 5 depicts details of the **ATM** LAN **Server** and the **ATM** interfaces of the network of FIGS. 1 and 2.

DRWD FIG. 6 depicts three **ATM** LANs configured on a three-switch **ATM** network.

DRWD FIG. 7 is a representation of the details of the **ATM MACs** of stations S0, S1, S2 and S3 from FIG. 6.

DETD In FIG. 1, an **ATM** network system is shown in which two or more computer stations 10 are interconnected by an **ATM** network 11 for network communication. The stations 10 include the station S0, S1,

. . . Ss designated 10-0, 10-1, . . . , 10-s. The **ATM** network system of FIG. 1 employs, for example, the top six of the seven OSI model layers. The OSI model physical layer 1 is replaced with a **ATM** interface which operates in an asynchronous transfer mode ( **ATM**) in accordance with the B-ISDN protocol.

DETD In FIG. 2, the **ATM** network 11 connects, by way of example, the S0 station 10-0 to the S1 station 10-1. The SO station 10-0 includes the top six OSI layers, namely, the application layer [0, 7], the presentation layer [0, 6], the session layer [0,5] and the transport layer [0,4]. The layers 7 through 4 in FIG. 2 are designated as the higher layers and operate in the conventional manner for the OSI model.

DETD In FIG. 2, the S0 station 10-0 includes the network layer [0,3] and the data link layer, [0, 2]. The data link layer [0,2] includes the logical link control (LLC) sublayer and the media access control (**MAC**) sublayer. The **MAC** sublayer in the data link layer [0, 2] connects to a **ATM** interface 13-0. The **ATM** interface 13-0 operates in accordance with the B-ISDN protocol defined by the CCITT.

DETD In FIG. 2, the S1 station 10-1 has the higher layers including the application layer [1,7], the presentation layer [1,6], the session layer [1,5] and the transport layer [1,4]. The S1 station 10-1 also includes

the network layer [1,3] and the data link layer [1,2] that connects to the **ATM** interface 13-1. In FIG. 2, the **ATM** interface 13-0 for the S0 station 10-0 and the **ATM** interface 13-1 for the S1 station 10-1 connect to a **ATM** switch 13' in the **ATM** network 11. The **ATM** interfaces 13-0 and 13-1 and **ATM** switch 13' operate in accordance with an **ATM** architecture for **ATM** communicationn. The **ATM** LAN communication is under control of an **ATM** LAN **server** 12 in the **ATM** network 11.

DETD In FIG. 2 each of the higher layers in the S0 station 10-0 and in the S1 station 10-1 function in a well known manner in accordance with the OSI model. Also, the network layer [0, 3] in the S0 station 10-0 and the network layer [1, 3] in the S1 station 10-1 conform to the model OSI The data link layer [0,2] in the S0 station 10-0 and the data link layer [1,2] in the S1 station 10-1 have OSI compatibility. The compatibility with the OSI model at the data link layer enables the **ATM** network system of FIGS. 1 and 2 to be compatible with other local area networks and other networks that conform to the OSI model from layer [2] and above. Below the OSI layer [2], the communication and connections are compatible with the B-ISDN model of the CCITT.

DETD In FIG. 3, the data link layer [2] includes the LLC sublayer and the **MAC** sublayer. The LLC sublayer includes the Logical Link Control (LLC) 19 which is conventional in the data link layer of the OSI model.

DETD The data link layer [2] also includes the **MAC** sublayer which as a component of the data link layer [2]. The **MAC** sublayer typically may include other **MAC** sublayers in accordance with the standards IEEE 802.3, 802.4, 802.5, 802.6 and FDDI. **ATM** LANs are, therefore, capable of interoperating with a wide variety of media. **ATM** LANs interoperate with all IEEE 802 Local Area Networks and Metropolitan Area Networks using transparent bridges and routers. Stations connected to **ATM** LANs communicate with stations connected to any IEEE 802 LAN or MAN via a bridge.

DETD In accordance with the present invention, the data link layer [2] also includes a new **ATM MAC** sublayer 22 analogous to the other **MAC** sublayers 23. The **ATM MAC** sublayer 22 differs from the other **MAC** sublayers 23 in that the **ATM MAC** sublayer 22 communicates with the **ATM** switch 13 for **ATM** communication.

DETD In FIG. 3, the **ATM MAC** sublayer 22 includes one or more **ATM MACs** including, for example, **ATM MAC** 0, **ATM MAC** 1, . . . , **ATM MAC** M designated 21-0, 21-1, . . . , 21-M respectively. Each of **ATM MACs** 21-0, 21-1, . . . , 21-m defines an **ATM** local area network (**ATM** LAN). The **ATM MACs** of the **ATM MAC** sublayer 22 connect between the logical link control 19 and the **ATM** interface 13-0. The control of which of the stations (like the stations 10-0, 10-1, . . . , 10-s) are serviced by particular ones of the **ATM MACs** 21 of FIG. 3 is determined by the station management 20 within the ATMMAC sublayer 22. Other stations (or the same stations) may also be serviced by other local area networks such as Ethernet under control of the other **MAC** sublayers 23.

DETD In FIG. 3, the **ATM MAC** sublayer is capable of servicing the communication requirements of the stations 10-0 through 10-s of FIG. 1 in one or more **ATM** LANs. Stations can be switched from one **ATM** LAN to another **ATM** LAN under control of station management 20 without requirement of modifying the physical connection to the station. For this reason, the **ATM** LANs are virtual LANs.

DETD In FIG. 4, further details of the ATMMAC sublayer 22 and the **ATM** interface 13-0 of FIG. 3 are shown.

DETD In FIG. 4 the **ATM MAC** sublayer includes the station managemen[illegible]0 and the **ATM MACs** including th[illegible] **ATM MAC** 0, . . . . , **ATM MAC** M designated as 21-0, . . . , 21-M.

DETD In FIG. 4, the **ATM MAC** 0 includes the multicast **address resolution** 24, the unicast **address resolution** 25, the frame 26 and the connection management 27.

DETD In FIG. 4, the **ATM** interface 13-0 includes the signaling protocol 28 in the control plane, the **ATM** ADAPTATION LAYER (AAL) 29, the **ATM** layer 30 and the physical layer 31.

DETD In FIG. 3, the higher layers [7,6,5,5] and [3] are conventional while the data link layer [2] includes the LLC sublayer and the **ATM MAC** sublayer to implement the Asynchronous Transfer Mode Local Area Networks (**ATM** LANs). Such an implementation is provided with newly defined Media Access Control (**MAC**) including addressing protocols. The **ATM** LAN provides support for the LLC sublayer by means of connectionless **MAC** sublayer service in a manner consistent with other IEEE 802 local area networks (LAN) and metropolitan area networks (MAN). The **ATM** LAN interface is built on the user-to-network interface for the **ATM** layer and the **ATM** adaptation layer (AAL).

DETD An **ATM** LAN includes a set of **MAC** entities which share a common group address space for the purposes of establishing multicast connections. Each station has one or more **ATM MAC** entities per physical connection to an **ATM** network. The network **ATM** LAN service provides the station with **ATM** LAN configuration information needed for **ATM MAC** operation. Included in this information is the number of **ATM** LANs the network has configured for that station.

DETD The user-to-network interface at the LLC and **MAC** levels is defined for the **ATM** LAN Architecture in a manner analogous to other Data Link Layer architectures.

DETD

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1.3 **ATM** LAN Functionality

An **ATM** LAN has the following characteristics:

addressing- all LANs connected by **MAC** bridges use 48 bit addressing

unicast- all stations can send frames to any other station in the LAN

duplication- frames are not duplicated

broadcast- all stations can broadcast to every other station in a LAN

multicast- any station can send to any group address and any station can register to receive frames for any group address

promiscuity- any station may chose to receive all frames with group destination addresses

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DETD 1.4 **ATM** LANs

DETD An **ATM** LAN is a local network having a set of stations which share a common group address space for the purpose of establishing multicast connections. An **ATM** LAN is implemented using services of **ATM** LAN **MAC**, **ATM** signaling and **ATM** Adaptation Layers. Stations may participate in more than one **ATM** LAN. **ATM** LANs may be bridged together using **MAC** bridges.

DETD **ATM** LANs are sometimes called Virtual LANs because they are not limited by the limitations of any physical media characteristics. A single underlying **ATM** network may support many **ATM** LANs. A station with a single **ATM** interface may be connected to many separate **ATM** LANs. There are no inherent limitations

in the **ATM** LAN protocol itself to restrict either the physical extent or the number of stations in a particular **ATM** LAN. Practical limitations, such as multicast traffic, usually limit the size and scope of **ATM** LANs.

DETD **ATM** LANs interoperate with a wide variety of media.

**ATM** LANs can interoperate with all IEEE 802 Local Area Networks and Metropolitan Area Networks using transparent bridges and routers. Stations connected to **ATM** LANs are able to communicate with stations connected to any IEEE 802 LAN/MAN connected via bridge.

DETD 2 **ATM** LAN Architecture

DETD An **ATM** LAN includes a set of procedures and protocols which work together to provide the services found in IEEE 802 LANs. The AAL and **ATM** protocols defined by CCITT are augmented by the **ATM** LAN **MAC** layer which maps unacknowledged **MAC** PDUs (**MAC** Protocol Data Units) onto unacknowledged AAL PDUs transmitted over virtual connections provided by the **ATM** physical layer. The **ATM** **MAC** manages connections using an **ATM** signaling protocol.

DETD 2.3 Station **ATM** LAN **MAC**

DETD Each station has one **ATM** LAN module per physical **ATM** interface. Each **ATM** LAN module provides **MAC** services via one or more **ATM** **MAC** entities. The **ATM** LAN **server** provides the **ATM** LAN **MAC** with configuration parameters.

DETD ______________________________________

2.3.1 **ATM** **MAC** Functions

The **ATM** **MAC** layer provides the following functions:

**ATM** LAN Configuration-
determines the number of **ATM** LANs which have been configured for the station and the operational parameters needed to establish multicast connections for each **ATM** LAN.

**MAC** PDU Framing-
**MAC** SDUs (Service Data Units) are encapsulated in an AAL specific framing.

**Address Resolution-**
IEEE 802. 48 bit **MAC** addresses are mapped onto E.164 **ATM** addresses.

Connection Management-
establishes and releases virtual connections for transmission of **MAC** PDUs (Protocol Data Units) and reception of frames addressed to registered group (multicast) addresses.

Multicast Service-
protocol and procedures are defined for transmission and reception of frames with group addresses. The network provides unreliable delivery via multicast service. The interface to the multicast service is AAL specific. The interface to be used is determined by configuration management.

2.3.2 **ATM** **MAC** Entity Service Interface

The **ATM** **MAC** entity provides the following service interface to **MAC** users

| Primitive | Parameters |
|---|---|
| M.sub.-- UNITDATA.request | |
| | destination address |
| | source address |

**mac** service data unit
M.sub.-- UNITDATA.indication
destination address
source address
**mac** service data unit
M.sub.-- REGISTER.sub.-- ADDRESS
group address
M.sub.-- UNREGISTER.sub.-- ADDRESS
group address
M.sub.-- REGISTER.sub.-- ALL
M.sub.-- UNREGISTER.sub.-- ALL

---

DETD 2.4 **ATM** Adaptation Layer

DETD 2.5 **ATM** Signaling Protocol

DETD The **ATM** LAN signaling protocol contains a subset of the functions in Q.93B. It provides the following services:

DETD 2.6 **ATM** LAN **Server**

DETD The **ATM** LAN **server** provides configuration and multicast services. It provides operational parameters for each **ATM** LAN in which each **ATM** station is configured.

Membership in **ATM** LANs is controlled via policies implemented by the **server**. These policies may vary between **ATM** LAN providers. The **ATM** LAN configuration protocol defines the information provided by stations with which **servers** may implement policies. Two policies which can be implemented are "port based configuration" and "station based configuration". The **ATM** LAN **server** may use the physical cabling to determine LAN membership. This is called "port based configuration". Alternatively, the **ATM** LAN **server** may use station **MAC** addresses to determine LAN membership. This is called "station based configuration". The same station to **server** protocol is used in either case. The station is not affected by the configuration policies implemented. When requesting **ATM** LAN configuration parameters, the station always provides its **MAC** address(es).

DETD

STATION TABLE
(VLAN MEMBERSHIP)

| VLAN | **MAC**.sub.-- ADDRESS |
| --- | --- |
| VLAN 1 | **MAC**.sub.-- Add[0](S1), **MAC**.sub.-- Add [1](S1), **MAC**.sub.-- Add [5](S5) . . . |
| VLAN 2 | **MAC**.sub.-- Add[2](S2), **MAC**.sub.-- Add [6](S6) . |
| . . | |
| VLAN 3 | **MAC**.sub.-- Add[0](S1), **MAC**.sub.-- Add [3](S3), **MAC**.sub.-- Add [4](S4) . . . |

PORT TABLE
(VLAN ASSOCIATION)

| Port Addresses [s/p#] | VLAN |
| --- | --- |
| PA [2,2], PA [2,3], PA [2,4], PA [2,5] | VLAN [3] |
| PA [2,6], PA [2,7], PA [2,8], PA [2,9] | VLAN [2] |
| . . . | . . . |
| PA [2,3], PA [3,4] | VLAN [3] |
| . . . | . . . |

DETD Each station establishes a VC to an **ATM** LAN **server**

for each physical interface. A well known group address is used. If redundant ATM LAN **servers** are providing configuration and multicast service, this service is transparent to the **ATM** station. The **servers** agree amongst themselves which ones will serve any particular station. The **servers** may elect to distribute responsibility for multicast service over several **servers**. This election is transparent to the station.

DETD 3 **ATM** LAN Configuration Management

DETD A station may belong to one or more distinct **ATM** LANs. The station will then have been configured with one or more **MAC** entities each having a unique **MAC** address.

DETD At power-on, the station establishes a VC to the network **ATM** LAN **server**. The station ATMMAC sends a configuration enquiry to the **ATM** LAN **server**. The enquiry contains the station's **MAC** address, alan.sub.-- **mac**.

DETD

```
struct alan.sub.-- req { /* configuration request */
u.sub.-- char        alan.sub.-- proto;
u.sub.-- char        alan.sub.-- pdu.sub.-- type;
u.sub.-- short       alan.sub.-- seqnum;
struct atm.sub.-- addr
                     alan.sub.-- mac;
};
```

---

DETD Using the unique **MAC** address, alan.sub.-- **mac**, the **ATM** LAN **server** determines the number of **ATM** LANs configured for that station and the configuration for each connected **ATM** LAN. A configuration response is sent to the station.

DETD The configuration response contains one alans.sub.-- parms per **ATM** LAN. For each **ATM** LAN the configuration manager activates an **ATM MAC** entity. The parameters in the alan.sub.-- parms element control the configuration parameters of each **ATM** LAN "tap".

DETD Each **ATM** LAN `tap` is described by the following parameters. The alan.sub.-- config and alan.sub.-- update messages contain one or more alan.sub.-- parms structures.

DETD

```
struct alan.sub.-- parms {
int                  alan.sub.-- version;
int                  alan.sub.-- aal;
struct atm.sub.-- addr
                     alan.sub.-- port;
struct atm.sub.-- addr
                     alan.sub.-- mcast.sub.-- base;
struct atm.sub.-- addr
                     alan.sub.-- lan.sub.-- uid[ ];
int                  alan.sub.-- num.sub.-- mcast;
u.sub.-- short       alan.sub.-- mid;
u.sub.-- short       alan.sub.-- mtu;
};
```

---

DETD The alan.sub.-- aal parameter specifies which AAL is used for multicast frames. Currently defined values are 4 and 5 for AALs 4 and 5 respectively. The alan.sub.-- port is the port address from which VCs are setup for this **ATM** LAN. The **ATM** LAN **server** may specify different port addresses for different taps or may specify the same for all. The **ATM MAC** entity treats this E.164 address as an unstructured bit string.

DETD The **ATM** LAN manager allocates a range of E.164 group address space for each **ATM** LAN. The alan.sub.-- mcast.sub.-- base is E.164 group address which is used in conjunction with alan.sub.-- num.sub.-- mcast (the number of group addresses allocated to the

**ATM** LAN) to map IEEE 802.1 group addresses onto the E.164 group address space. AAL and multicast service parameters are protocol specific.

DETD AAL multicast service requires that multicast AAL PDUs be transmitted using multiplexing identifiers, (MIDs), provided by the **ATM** LAN **server**. This allows multicast service to be provided via replication functions often found in **ATM** switch fabrics. Each **ATM MAC** entity is assigned a LAN unique MID for transmission and must reassemble AAL using the full 10 bit MID.

DETD Each **ATM** LAN is assigned a globally unique identifier, alan.sub.-- lan.sub.-- uid. This is a 128-bit name created by the **ATM** LAN **server**. The **ATM** LAN **server** provides alan.sub.-- parms structures for the requested **MAC** addresses. If the station requests configuration parameters for two **MAC** addresses which belong to the same **ATM** LAN, two identical alan.sub.-- parms elements are returned.

DETD Once the **ATM MAC** entities have been created, the configuration manager periodically sends keep alive frames on the configuration SVC. If the configuration SVC is released the configuration manager destroys the **ATM** LAN entities it created. If after some number of retries the **ATM** LAN **server** does not respond to keep alive packets, the configuration manager will release the configuration SVC and destroy **ATM MAC** entities.

DETD

Configuration Acquisition Protocol State Machine

| State | Event | Actions | Newstate |
| --- | --- | --- | --- |
| Inactive | Activate | Setup Request Start timer C1 | Wait for Setup Conf |
| Wait for Setup Conf | Release Ind | Setup Request, Start timer C1 | Wait for Setup Conf |
| | Setup Conf | Config Request, Start Timer C2 | Wait for Setup Conf |
| Wait for Setup Conf | Timeout | Config Request, Increment Retries | Wait for Setup Conf |
| | Max retries | Release, Setup Request | Wait for Setup Conf |
| | Config Resp | Activate **MAC** Entities | Active |
| Any state | Deactivate | Deactive active | Inactive |
| .linevert split.Active | | **MAC** entities, Re- lease configuration VC | |
| | Release Ind | Setup Request, Start timer C1 | Setup Request, Start timer C1 |

DETD 4. **ATM** LAN **MAC**

DETD The **ATM** **MAC** maps IEEE 802.1 flat 48 bit addresses to 60 bit hierarchical E.164 **ATM** addresses by the **address resolution** function. Individual IEEE 802. addresses are mapped into port addresses via the **ATM** **Address Resolution** Protocol, **ATM** ARP. Group IEEE 802.1 addresses are mapped to **ATM** group addresses using a fixed algorithm.

DETD Once an **ATM** address is determined, the **ATM** signaling protocol is used to establish a virtual connection. The connection is either a unicast connection or a multicast connection depending upon whether the **ATM** address is an individual or group address. Connection management is responsible for establishing and clearing these connections.

DETD **ATM** LAN uses the same **MAC** framing as 802.6. **ATM** LANs use 48 bit **MAC** addresses to enable interoperability with 802 LANs via **MAC** bridges. As shown in the following table, addresses are encoded as byte quantities as per 802.6.

DETD Two types of addresses are used in an **ATM** LAN, station **MAC** addresses and **ATM** (or port) addresses. Both types of addresses may either be individual or group addresses.

DETD **MAC** station addresses identify individual stations connected to an **ATM** LAN. Station addresses are 48 bit universally administered 802.1 **MAC** addresses. These **MAC** addresses enable interoperability with 802.1D LAN **MAC** bridges. Station addresses are used as **MAC** frame source or destination addresses.

DETD **MAC** group addresses are used to address frames to multiple destination stations on an **ATM** LAN. Group addresses are used to set up virtual connections to multiple destination stations without knowledge of those stations' individual addresses. They are used to provide multicast and broadcast services. Broadcast is a a specific instance of multicast with all stations receiving frames with well defined group address, specifically all 1's. Group addresses are 48 bit universally or locally administered 802. **MAC** addresses. The group address with all bits set to one is the broadcast address.

DETD **ATM** Port addresses or port addresses or **ATM** individual addresses identify physical ports on switches. They are hierarchical 60 bit E.164 addresses dynamically assigned by the network. Each virtual connection has a port address for at least one endpoint. Port addresses are used in **ATM** ARP and Signaling PDUs.

DETD **ATM** group addresses (or multicast port addresses) identify an **ATM** level multicast group. They are used in signaling PDUs.

DETD

| Address | Type | Padding | Address |
|---|---|---|---|
| **ATM** port address | 110x | no padding | 60 bits |
| **ATM** group address | 111x | no padding | 60 bits |
| **MAC** station address | 1000 | 12 bits | 48 bits |
| **MAC** group address | 1000 | 12 bits | 48 bits |

x indicates whether the address is publicly or privately administered

DETD 4.3.2 **ATM** LAN Multicast

DETD In an **ATM** LAN, multicast capability is provided by the multicast **server** which is part of the LAN **server**. Stations use that service by establishing virtual connections to the **server** using the multicast base **ATM** address provided in the configuration parameters (alan.sub.-- parms). The multicast base address is a privately administered group E.164 address. Virtual connections with a group **ATM** address at one endpoint are multicast VCs. When setting up a multicast VC the station may request transmit only access so that it will not receive frames transmitted on that VC.

DETD IEEE 802.1 48 bit addressing provides for up to 2.sup.46 possible group addresses all registered by various stations in one LAN. Few **ATM** networks could support 2.sup.46 virtual connections. To bridge this gap in service offering and network capability, each **ATM** LAN is configured to support a small (typically 100s) number of multicast circuits. This number is exported in the alan.sub.-- parms configuration element. Each **ATM** **MAC** entity is also provided with a multicast base address which is treated as a 64-bit integer. These two numbers are used to map many 48-bit IEEE group addresses to fewer **ATM** group addresses which are then used to setup multicast connections. If alan.sub.-- num.sub.-- multicast is zero, then the 48-bit group address is added to alan.sub.-- mcast.sub.-- base. Otherwise the 48-bit group address is treated as a 16 most significant bits of the 48-bit group address are Exclusive-Ored into the 32 least-significant bits, the result is divided by alan.sub.-- num.sub.-- mcast and the resulting remainder is added to alan.sub.-- mcast.sub.-- base. In either case, the result value is used as a group address to set up a multicast connection for that group address.

DETD Each **ATM** **MAC** entity maintains a list of group addresses for which its users have requested it receive frames. Each of these group addresses is mapped onto a **ATM** group address when the **MAC** entity is given is alan.sub.-- parms information, that is, when it becomes active. There after, the **ATM** **MAC** entity will maintain a multicast connection for each port address derived from the above computations. Note, several **MAC** group addresses may map onto one group port address. In this case, only one connection is maintained for those **MAC** group addresses. If the network releases a multicast connection, the **ATM** **MAC** entity will re-establish another one.

DETD The **ATM** **MAC** entity will always maintain a multicast connection for the group port address derived from the broadcast **MAC** address.

DETD 4.3.4 Transmission of Multicast **MAC** PDUs

DETD When an ATMMAC entity is presented with a M.sub.-- UNITDATA.request with a group destination address it maps the group **MAC** address to the group **ATM** address, and transmits the **MAC** PDU on the connection established to that port address. If no connection is already established, the frame is queued until one is established. Multicast connections setup solely for the transmission of multicast PDUs are aged in the same fashion as those setup for unicast PDUs.

DETD 4.3.5 Reception of Multicast **MAC** PDUs

DETD The group destination addresses in received **MAC** PDUs are checked against the list of registered group addresses. If the group addresses are not registered, the frame is dropped. This dropping is necessary because transmitters may map **MAC** group addresses onto a multicast connection established to register other group addresses.

DETD Multicast connections established for registered group addresses are not aged. They are not released until the last **MAC** service users want to receive frames addressed to any of the group addresses mapped

onto that connection.

DETD The **ATM** **MAC** entity maintains reference counts on the number of **MAC** service users which have registered a group address. A reference count on the multicast connection is maintained for each **MAC** group which maps onto the connections group **ATM** address.

DETD Stations connected to multicast VCs can receive frames from many sources simultaneously. The multiplexing identifier (MID) in the ALL4 SAR header is used to correctly reassemble these frames. MIDs are unique within a given **ATM** LAN. The LAN **server** assigns a unique MID to each port address.

DETD Up to 1023 stations may be connected to an **ATM** AAL 3/4 LAN. Each station has a globally unique 48-bit address per **ATM** LAN. Each station is assigned one MID per **ATM** LAN (local port address to the station) to be used when transmitting frames on multicast VCs. Stations may not transmit more than one frame simultaneously on multicast VCs with the same local port address. Each station implements **MAC** level address filtering for frames received on multicast VCs.

DETD Each station has a multicast filter which is used to filter frames received on broadcast VCs. This filter may be implemented in hardware or software. The filter is necessary because each **ATM** network provides limited multicast service and stations may broadcast unicast frames.

DETD AAL 5 does not provide for multiplexing frames on a single VC simultaneously. The mid field in the alan.sub.-- parms structure is ignored. There is no limit on the number of stations (or **ATM** **MACs**) which may belong to an AAL 5 **ATM** LAN.

DETD 4.4 **ATM Address Resolution** Protocol

DETD Individual IEEE 802.1 **MAC** addresses are mapped into port addresses via the **ATM Address Resolution** Protocol (**ATM** ARP). Once the port address is determined the **ATM** signaling protocol is used to establish a virtual connection.

DETD 4.4.1 **ATM** ARP Operation

DETD Stations connected directly to **ATM** LANs will, conceptually, have address translation tables to map **MAC** addresses (both station, and group addresses) into virtual connection identifiers. The **MAC**-to-port table, provides mappings from **MAC** addresses to port addresses.

DETD The **MAC** transmission function accesses this table to get next hop port address given destination station address. This table is updated when new station address to port address mappings are learned via **ATM** ARP and when **MAC** group address to **ATM** group address mappings are computed. The entries in the **MAC** to port table are updated when **ATM** ARP requests and replies are received.

DETD When the **MAC** layer is presented with a frame for transmission, it looks up the destination address in the station to port address table. If an entry is found, connection management selects the appropriate virtual connection upon which the frame should be transmitted.

DETD If no entry is found, a new entry is allocated for that **MAC** address. If the **MAC** address is a group address, an **ATM** group address is computed using an AAL specific function. This operation permits the broadcast VC to be established without sending **ATM** ARP requests. Mapping individual **MAC** addresses to port addresses is accomplished by broadcasting an **ATM** ARP request for the **MAC** addresses to all stations connected to the

**ATM** LAN. The **ATM** ARP request carries the sender's **MAC** and port address mapping. All stations receive the request. The station with the specified **MAC** address responds with an **ATM** ARP reply. The responder updates its **MAC**-to-port table using the information in the request. The reply carries both the responders' and the requestors **MAC** and port addresses. When the requestor receives the **ATM** ARP reply, it updates its port-to-**MAC** address table.

DETD

| | | |
|---|---|---|
| **MAC** to Port entry | | |
| Station Address 48 | | |
| | Next Hop Port | Status |
| Bit 802.1 **MAC** | Address E.164 | |

DETD The requesting station must transmit **MAC** frames on broadcast connections until it receives responses to its **ATM** ARP requests. It may then set up a connection using the port address in the reply. Usually, the responder sets up the connection before replying.

DETD The **ATM** ARP function times out entries in the **MAC** -to-port table when they have been idle for some time. Connection management is notified when entries in the **MAC**-to-port table are added, updated or deleted. Connection management notifies **ATM** ARP when connections are established and released. Entries in this table are deleted when an SVC establishment to the port address fails. They are deleted when the connection corresponding to an entry is released.

DETD 4.4.2 **ATM** ARP PDUs

DETD **ATM** ARP requests and replies are encapsulated in 802.2 LLC and the appropriate AAL for the connection upon which they are sent. **ATM** ARP requests are always broadcast. Therefore they are encapsulated in the AAL used for multicast connections. **ATM** ARP replies are usually sent on point to point connections. The **ATM MACs** negotiate the AAL to be used for that connection. The reply is then encapsulated in 802.2 LLC and the specific AAL framing.

DETD The **ATM** ARP messages are:

DETD

```
/*
 *   ATM Address Resolution Protocol.
 */
struct atm.sub.-- arp {
u.sub.-- short
              aa.sub.-- llp; /* lower layer protocol */
u.sub.-- short
              aa.sub.-- ulp; /* upper layer protocol */
u.sub.-- char
              aa.sub.-- llp.sub.-- len;
u.sub.-- char
              aa.sub.-- ulp.sub.-- len;
u.sub.-- short
              aa.sub.-- msg.sub.-- type;
u.sub.-- char
              aa.sub.-- sender.sub.-- port[8];
u.sub.-- char
              aa.sub.-- sender.sub.-- mac[6];
u.sub.-- char
              aa.sub.-- target.sub.-- port[8];
u.sub.-- char
              aa.sub.-- target.sub.-- mac[6];
};
/* aa.sub.-- msg.sub.-- type' s */
#define ATM.sub.-- ARP.sub.-- REQUEST 1
```

DETD The aa.sub.-- ulp.sub.-- len and aa.sub.-- llp.sub.-- len fields are always 6 and 8 respectively. The aa.sub.-- ulp field is set to 16. The sender **mac** and port addresses are set to the sender's **Mac** and Port addresses for request and non-proxy reply messages. The aa.sub.-- send.sub.-- **mac** field in proxy replies contains the aa.sub.-- target.sub.-- **mac** from the corresponding request. The aa.sub.-- target.sub.-- **mac** is always set to the **Mac** address needing resolution in requests and it is set to the requestor's **Mac** address in replies. The aa.sub.-- target.sub.-- port is undefined in requests and in replies it contains the aa.sub.-- sender.sub.-- port from the corresponding request. The recipient of a reply verifies that the aa.sub.-- target.sub.-- port corresponds to one of its own port addresses.

DETD Once a **MAC** address has been resolved to a **ATM** address a connection to the station receiving frames for that **MAC** address can be set up and those frames can be transmitted directly to that station rather than broadcast. Connection management is responsible for defining the connection establishment and release policies. The **ATM** signaling protocol is used to establish connections for **ATM** LAN **MAC** frames. A specific upper layer protocol identifier is reserved for **ATM** LAN **MAC** frames.

DETD Connections are established when an Unacknowledged Data Request needs to be transmitted to a **MAC** address for which a to-**ATM** address mapping is known, but no connection to that **ATM** address, is established (or emerging). It is possible for two **MAC** entities to simultaneously establish connections to each other. When connection management receives connection setup SDU from **ATM** signaling, it checks to see if a connection to the peer port address already exists. If another connection exists (or is being established), the connection initiated from the lower port address is released. Thus there will never be more than one connection established between two **ATM** **MAC** entities.

DETD While a connection is being setup, frames which would be transmitted on that connection once it is established must be queued or dropped. Frames should not be broadcast. At least one frame must be queued. Implementations may chose to queue more. Once the connection is set up, any queued frames are transmitted. The first frame transmitted on a connection initiated by a station must be the **ATM** ARP response for the an **ATM** ARP request.

DETD Currently, distinct qualities of service may be defined for **ATM** **MAC** PDUS.

DETD Connections for which there is no **MAC**-to-**ATM** address mapping are held for the product of the number of **ATM** ARP retries and retry interval and then released. The **MAC**-to-**ATM** address mappings are aged separately.

DETD When **ATM** ARP deletes all the translations to a specific **ATM** address, all connections to that **ATM** address are released.

DETD When a connection is released, the **ATM** ARP function deletes all **MAC** to **ATM** translations for that connection's remote **ATM** address.

DETD Frame Reception Stations are responsible for performing filtering of incoming frames. Unicast addressed frames for other stations will be received on the broadcast VC. Multicast frames for unregistered multicast addresses may be received on multicast VCs. These frames are not passed up to the **MAC** service user.

DETD 4.7 **Address Resolution** and Connection Establishment Example

DETD In this example, the steps are described that are required for one station, called Lyra, to deliver a **MAC** UNITDATA SDU to another station, called Altera, assuming neither station has had any prior communication. It is assumed that both stations are part of the same **ATM** LAN. These steps are only required for the initial transmission from Lyra to Altera. Additional **MAC** PDUs may be transmitted on the connection setup by these steps until either station decides it no longer wishes to maintain the connection. In this example, **MAC** addresses are expressed in xx:xx:xx:xx:xx:xx form where each pair of hex digits, xx, is one octet for the address. Port addressees are expressed in the same form except that they have 8 octets.

DETD An **ATM MAC** service user on Lyra provides the **ATM MAC** with an UNITDATA SDU to be sent to station address 00:80:b2:e0:00:60. The **MAC** consults its **MAC** to port address table, but finds no translation.

DETD The **MAC** creates an **ATM** ARP request for **MAC** address 00:80:b2:e0:00:60. The request contains Lyra's own **MAC** and port addresses, 00:80:b2:e0:00:50 and d1:41:57:80:77:68:00:02 respectively. The **ATM** ARP is encapsulated in LLC/SNAP. The destination **MAC** address is ff:ff:ff:ff:ff:ff (the broadcast address). The **ATM MAC** recursively invokes itself to transmit the **ATM** ARP request.

DETD The **MAC** address to port address table is searched for the broadcast **MAC** address and the corresponding port address is obtained, f1:41:57:80:77:68:01:01. The station established a connection to this port address when the **ATM** LAN **MAC** entered the active state. The **ATM** ARP PDU is encapsulated in an 802.6 frame and passed to the AAL 4 function along with the MID associated with this **ATM MAC** entity for transmission of that multicast connection.

DETD The **MAC** must transmit the **MAC** SDU. In lieu of a valid **MAC** address to port address mapping the broadcast **MAC** to port mapping and associated connection are used. The **MAC** SDU is encapsulated in an 802.6 frame and passed to the AAL 4 function with the MID associated with this **ATM MAC** entity for transmission of that multicast connection.

DETD All the above took place on Lyra. The subsequent steps take place on Altera as it receives the **ATM** ARP and the **ATM MAC** PDU containing user data.

DETD The **ATM** ARP is received by all **MAC** entities including Altera. The other **MACs** determine that the requested **MAC** address is not theirs and ignore the request. Altera determines that its **MAC** address is in the request. Altera updates its **MAC** to port address table with Lyra's **MAC** and port addresses provided in the **ATM** ARP request. Next an **ATM** ARP reply is constructed using Altera's port and **MAC** addresses. This request, in the form of an **MAC** SDU with Lyra's **MAC** address as the destination, is passed to the **ATM MAC** entity.

DETD The **ATM MAC** looks up Lyra's **MAC** address in the **MAC** to port address table. It finds Lyra's port address. The port to VCI table is searched using that port address. No entry is found. Connection management is invoked to establish a connection to Lyra. Connection management passes a SETUP request to **ATM** signaling. The **MAC** queues the **ATM** ARP response until the connection is established.

DETD Altera **ATM** signaling module sends a SETUP PDU to establish a connection to port address d1:41:57:80:77:68:00:02. The upper layer protocol (sometimes called upper layer compatibility) is the **ATM** LAN **MAC**. (This is not a function of the **ATM MAC**. But it is included for illustrative purposes.)

DETD Next all stations receive the **MAC** SDU containing the user data on the broadcast connection. All stations except Altera determine that the destination **MAC** address is not theirs and drop the frame.

Altera accepts the frame strips off the 802.6 and LLC/SNAP overhead and passes the frame up to the user function identified by LLC/SNAP.

DETD At this time, the SDU provided to Lyra's **ATM MAC** has been delivered to the appropriate **MAC** user on Altera. However, the **MAC** entities continue connection establishment and **address resolution** for subsequent communications between the two stations. The next sequence of operations occurs on Lyra.

DETD **ATM** signaling on Lyra receives a connection setup indication from the network. This indication is passed up to the upper layer protocol which in this instance is the **ATM MAC**.

DETD The **ATM MAC** receives a setup indication SDU from signaling. At this point Lyra knows some other station's **ATM MAC** is trying to setup a connection to it. The port to vci table is searched for a connection to the callers port address. In this case none is found. The connection is accepted by passing a CONNECT SDU to **ATM** signaling. The **MAC** starts an idle timer for the connection. Note, that the **ATM MAC** can not use this connection until an **ATM** ARP request or response is received indicating **MAC** addresses for stations accessible via the connection.

DETD Lyra's **ATM** signaling transmits a CONNECT PDU to the network. Typically, network communication is bi-directional. Assuming this is the case the **MAC** service user on Altera has responded to the **MAC** SDU indication with a **MAC** SDU request,. The following actions take place on Altera. The ordering of the arrival of **MAC** SDU and the CONNECT SDU are arbitrary.

DETD The **MAC** service user passed the ATMMAC an SDU with a destination **MAC** address of 00:80:b2:e0:00:50 (Lyra's). The **MAC** finds the mapping from **MAC** address to port address learned when the **ATM** ARP request was received from Lyra. The **MAC** next finds that it is setting up a connection to Lyra's port address and that the connection is not yet established. A **MAC** PDU is created from the **MAC** SDU and queued waiting connection establishment.

DETD Altera **ATM** signaling receives a connect PDU. This is passed up to the **MAC** as a SETUP confirmation. The **ATM** signaling sends a CONNECT acknowledge PDU to Lyra. The connection is considered established.

DETD Altera's **ATM MAC**, upon receiving the SETUP confirmation, transmits all frames which were queued awaiting connection establishment. The **ATM** ARP reply is the first frame to transmitted. It is followed by the **MAC** PDU containing user data.

DETD At this TIME, **address resolution** and connection are complete on Altera. Any further frames addressed to Lyra's **MAC** address will use the new connection. The connection is not established on Lyra. Also Lyra still does not have a mapping for Altera's **MAC** address. The following actions complete **address resolution** and connection establishment on Altera.

DETD The **ATM** ARP reply is received on the connection which is still being setup. (Note most **ATM** networks have slower signaling channels than payload channels. Typically the **ATM** ARP response will be received prior to the CONNECT acknowledge PDU.)

DETD The **MAC** enters Lyra's **MAC** address to port address mapping in the **MAC** to port table. At this point any **MAC** UNIT-DATA requests will be queued until the SETUP complete indication for the connection is passed up from **ATM** signaling.

DETD The **MAC** PDU containing user data from Lyra's **MAC** users is received. The 802.6, LLC and SNAP headers are removed and a **MAC** UNITDATA indication is passed up to the appropriate **MAC** service user.

DETD Altera's **ATM** signaling receives a CONNECT.sub.-- ACK PDU. This

moves the connection into established state. The **ATM** signaling function passes up a SETUP COMPLETE indication informing the **ATM** **MAC** it may transmit on the connection. Connection management starts its idle timer for the connection.

DETD The connection is now established on both stations. One or more **MAC** UNITDATA SDUs have been delivered. The connection will timed out as per local policy decisions.

DETD **ATM** LAN Code Overview

DETD The **ATM** LAN **MAC** code in the appendix is organized by functional components and Operating System (OS) dependencies. The file if.sub.-- **atm**.c contains the routines which contain OS dependencies and which are typically implemented differently for each OS. The unicast unit 25 and multicast unit 24 **address resolution** functions are implemented in the file atmarp.c. The file atmarp.h contains the definitions for the **ATM** ARP protocol and the structures used by atmarp.c to implement the protocol. The file **atm**.c implements the function of connection management unit 27. Those routines interact with the **ATM** signaling function to establish and release connections. The framing unit 26 function is implemented in the OS specific file if.sub.-- niu.c in the routines niuoutput(), **atm**.sub.-- **mac**.sub.-- input() which encapsulate and decapsulate frames respectively. The station management unit 28 functions are implmenented in **atm** .sub.-- init.c and in parts of the **ATM** signaling unit 28 in the files svc.c, svc.sub.-- utl.c and svc.sub.-- pdu.c. The **ATM** LAN **server** unit 12 functions are implemented in the files lm.c, lm.sub.-- cfg.c, lm.sub.-- mgmt.c and lm.sub.-- util.c.

CLM What is claimed is:

1. For a communication system including a plurality of ports where each port has a unique port address, where sending ports have sending port addresses, and where receiving ports have receiving port addresses, and where the communication system includes a plurality of stations where each station has, a unique station address distinguishing the station from other stations, a connection to one of said ports for communications between source stations at the sending ports and destination stations at the receiving ports, packet means for providing packets for transferring information, said information including a destination station address for addressing one or a group of said destination stations, and packet converter means connected to said packet means for converting between packets and cells for transfers between stations; an apparatus comprising: connection means for connecting said sending ports to said receiving ports, **address resolution** means for determining a particular one or more of said receiving port addresses corresponding to said destination station address, said **address resolution** means including multicast means for multicasting said destination station address from a

particular one of said source stations to a group of said destination stations, said multicast means including, response means for providing said particular one or more of said receiving port addresses corresponding to said destination station address, and reply means for transmitting said particular one or more of said receiving port addresses to a sending port; and connection management means connected to receive said one or more receiving port addresses from said **address resolution** means for requesting connections through said networking apparatus connecting said sending ports to said receiving ports whereby packets are transferred from source stations to destination stations by cell transfers.

6. In the system of claim 1 wherein said connection means includes a single **ATM** switch.

9. For a communication system including a plurality of ports, including sending ports and receiving ports, where each port has a unique port address, where sending ports have sending port addresses and receiving

ports have receiving port addresses, and including a plurality of stations where each station has, a unique station address distinguishing the station from other stations, a connection for an **ATM** network at one of said ports whereby source stations at the sending ports communicate with destination stations at the receiving ports, packet means for providing packets for transferring information where the information includes a destination station address for addressing one or a group of said destination stations, packet converter means connected to said packet means for converting between packets and cells for transfers between stations, an apparatus comprising: one or more **ATM** switches for connecting said sending ports to said receiving ports for communications through said one or more **ATM** switches to form the **ATM** network, **address resolution** means for determining a particular one of said receiving port addresses corresponding to said destination station address, said **address resolution** means including multicast means for multicasting said destination station address from a particular one of said source stations to a group of said destination stations, wherein said group of destination stations that receive the multicast destination station address constitutes a local network, connection management means connected to receive said particular one of said receiving port addresses from said **address resolution** means for requesting connections through said **ATM** network connecting said sending ports to said receiving ports whereby packets are transferred from source stations to destination stations by cell transfers through said **ATM** network, local network management means for controlling which of said stations are included within said group of destination stations that receive the multicast destination station address.

15. For a communication system including a plurality of ports, including sending ports and receiving ports, where each port has a unique port address, where sending ports have sending port addresses and receiving ports have receiving port addresses, and including a plurality of stations where each station has, a unique station address distinguishing the station from other stations, a connection for an **ATM** network at one of said ports whereby source stations at the sending ports communicate with destination stations at the receiving ports, packet means for providing packets for transferring information where the information includes a destination station address for addressing one or a group of said destination stations, packet converter means connected to said packet means for converting between packets and cells for transfers between stations, an apparatus comprising: one or more **ATM** switches for connecting said sending ports to said receiving ports for communications through said one or more **ATM** switches to form the **ATM** network, identification means for identifying a plurality of groups of stations, each group constituting a local network of the stations in the group, **address resolution** means for determining a particular one or more of said receiving port addresses corresponding to said destination station address, said **address resolution** means including multicast means for multicasting said destination station address from a particular one of said source stations to a group of stations constituting a local network including the source station identified by said identification means, wherein said multicast means includes, response means for providing said particular one or more of said receiving port addresses corresponding to said destination station address, reply means for transmitting said particular one or more of said receiving port addresses to a sending port through said **ATM** network, connection management means connected to receive said receiving

port addresses from said **address resolution** means for requesting connections through said **ATM** network to connect said sending ports to said receiving ports whereby packets are transferred from source stations to destination stations by cell transfers through said **ATM** network.

17. In the system of claim 15 wherein said management means includes means for transferring configuration parameters between stations and said **ATM** network.

18. In the system of claim 15 wherein said management means includes means for transferring multicast configuration parameters between stations and said **ATM** network.

20. In the system of claim 15 wherein said said one or more **ATM** switches comprises a single **ATM** switch.

31. In the system of claim 29 wherein each station has a physical connection to a pert of said **ATM** network and wherein said means for adding and deleting operates independently of the physical connection of each station.